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Instrumental ignorance

Questioning scientific ecologies of existential non-knowledge in green tech innovation, sustainability research, renewable energy development, and the human expansionist episteme

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This research explores critical innovative roles for conceptual assumptions, institutional amnesia, practiced self-deceit, material avoidance, dissembling, undone science, and other forms of applied ignorance. Ignorance is often conceptualized as a gap in technical expertise; however, ignorance may also arise through technical expertise and prove instrumental for scientific, technical, and finance experts. Specialists and organizations can draw upon ignorance to protect their symbolic values from material evidence that might otherwise challenge those values. Sharing ignorance through science journalism, academic publishing, and government communications relies on carefully crafted language that unknowledgeable actors would be unable to orchestrate. This work considers such instrumental roles of ignorance in the financing and development of solar cells, wind turbines, hydrogen infrastructure, bioenergy, electric vehicles, and other green tech innovations.

Clean energy innovation may constitute a seductive anticipatory knowledge framework that draws from an unorganized ecology of ignorance, manifesting consciously, subconsciously, or some combination thereof. The resulting spectacles can protect us from forbidden questions about our expanding presence and culpability in ecological decline.

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ZEHNER

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OZZIE ZEHNER

Instrumental ignorance

Questioning scientific ecologies of existential non-knowledge in green tech innovation, sustainability research, renewable energy development, and the human expansionist episteme

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Faculteit der Maatschappij- en Gedragswetenschappen

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English abstract

This research explores critical innovative roles for conceptual assumptions, institutional amnesia, practiced self-deceit, material avoidance, dissembling, undone science, and other forms of applied ignorance. Ignorance is often conceptualized as a gap in technical expertise; however, ignorance may also arise through technical expertise and prove instrumental for scientific, technical, and finance experts. Specialists and organizations can draw upon ignorance to protect their symbolic values from material evidence that might otherwise challenge those values. Sharing ignorance through science journalism, academic publishing, and government communications relies on carefully crafted language that unknowledgeable actors would be unable to orchestrate. This dissertation considers such instrumental roles of ignorance in the financing and development of solar cells, wind turbines, hydrogen infrastructure, bioenergy, electric vehicles, and other green tech innovations.

The current project proposes an extension of the sociological concept of expert non-knowledge to include a class or an age – the epoch of an entire field – that shares an encumbering worldview. Such existential ignorance may be self-serving to an entire discipline and be enabled in part by 1) physical displacement – technology's material effects occur far away so it is difficult to verify expert claims, 2) disciplinary isolation – scientific and policy expertise is often separated from manufacturing expertise, 3) moral caution erosion – descriptions may be technically correct within certain parameters and offer plausible deniability in context, and 4) prestige motive, which may include the profit motive but is characterized by an ego-protective denial that fuels an emblematic sense that one is fighting the just war.

Clean energy innovation may constitute a seductive anticipatory knowledge framework that draws from an unorganized ecology of ignorance, manifesting consciously, subconsciously, or some combination thereof. The resulting spectacles can protect us from forbidden questions about our expanding presence and culpability in ecological decline. This work draws upon agnotology, not to create competing truth claims, but rather to provisionally consider challenging questions in an attempt to triangulate what is left unknown, to ask why, and to consider inquiring differently in the

future. In short, the product of this method is not better answers, but different questions.

Nederlands abstract

Dit onderzoek verkent de essentiële rol van onwetendheid op het gebied van groene technologische innovatie. Het gaat na hoe belangrijke actoren en instituties onwetendheid kunnen opwekken om incongruenties tussen symbolische waarden en geleefde ervaring in stand te houden, specifiek binnen de technologische lijnen van zonnecellen, windturbines, waterstofinfrastructuur, bio-energie en elektrische voertuigen. Dit werk maakt gebruik van agnotologie, niet om concurrerende waarheidsclaims te creëren, maar meer om voorlopig uitdagende vragen te overwegen in een poging om het onbekende beter te trianguleren, om de waarom-vraag te stellen, en om te overwegen om in de toekomst op een andere manier te onderzoeken. Kortom, het resultaat van deze methode zijn geen antwoorden, maar vragen.

Onwetendheid wordt vaak geconceptualiseerd als een leemte in de technische deskundigheid die moet worden opgevuld, maar onwetendheid kan ook juist door technische deskundigheid ontstaan en nuttig zijn voor technische deskundigen. Het delen van verschillende vormen van onwetendheid via wetenschapsjournalistiek, academische publicaties en overheidscommunicatie kan bijvoorbeeld beroep doen op zorgvuldig uitgewerkte taal die onwetende actoren niet zouden kunnen organiseren. Wij zien kritieke innovatieve rollen voor conceptuele veronderstellingen, materiële vermijding, institutioneel geheugenverlies, beoefend zelfbedrog, en andere vormen van toegepaste instrumentele onwetendheid. Dit onderzoek stelt een uitbreiding voor van het fenomeen van onkunde tot een klasse of periode - het tijdperk van een heel veld - dat een bezwarend wereldbeeld deelt. Dergelijke gecultiveerde vormen van onwetendheid kunnen zichzelf ten dienste stellen van hun disciplinaire velden en worden gedeeltelijk mogelijk gemaakt door 1) fysieke verplaatsing - de materiële effecten van technologie vinden ver weg plaats, waardoor het lastig is om beweringen van deskundigen te verifiëren, 2) disciplinaire isolatie - wetenschappelijke en beleidsexpertise is vaak gescheiden van productiekennis, 3) morele voorzichtigheidserosie - beschrijvingen kunnen technisch correct en in de context plausibel te ontkennen zijn, en 4) prestigeoogmerk, dat het winstoogmerk kan omvatten maar gekenmerkt wordt door een ontkenning die het ego beschermt

en een symbolisch gevoel kweekt dat men de rechtvaardige strijd voert.

Schone energie-innovatie kan een verleidelijke anticiperende kennisleer vormen die put uit een ongeorganiseerde ecologie van onwetendheid, die zich bewust, onbewust of in een combinatie daarvan manifesteert. Het resulterende oogpunt kan ons beschermen tegen vragen over onze groeiende aanwezigheid en schuld in de achteruitgang van ecosystemen.

Summary of Chapter 1

The story of renewable energy is a seductive and powerful organizing principle of activism and capital. Beyond the physical attributes of these technologies, what else does the story of renewable energy do for us on an intellectual and emotional level? How does it protect us? How does it shape our conceptions of ourselves as moral citizens? And, how does it influence the questions we even think to ask?

Throughout academia, government, industry, and environmental organizations, alternative energy technologies stand as prominent components in the storytelling surrounding sustainable futures. In pursuing the material account of energy technologies, this research humbly follows *episodes of discordance* between symbolic conceptions and observed material attributes principally through 1) comparing claims by renewable energy advocates against their own facts and figures, occasionally transformed through straightforward multiplication or division, and 2) elucidating potential internal contradictions within the renewable energy belief system as a matter of reasoning.

We typically understand the value of asking questions as a driving force behind scientific and technological development but we may additionally consider the potential for economic, political, and scientific value in *not* asking questions as well.

This research contrasts green energy expectations with material factors to develop unasked questions involving, for instance, urban myths (e.g., solar cells are made from sand), assumptions (e.g., alternative energy is of comparable quality to fossil fuel energy and can offset its use), instrumental ignorance (e.g., solar cost drops reflect Moore's law), trained incapacity (e.g., solar and wind energy is low- or zero-carbon), and related agnotological inquiries.

This chapter presents some fundamental questions:

1) What, symbolic dispositions of energy technologies are emanant in the public realm involving sustainability and in what ways do these appear to come into alignment or discordance with the measured or otherwise observed experience of these technologies in practice?

2) In what ways do forms of non-knowledge – such as strategic ignorance, assumptions, trained incapacity, misdirection, and denial – contribute toward binding together otherwise incommensurate systems of belief about renewable

energy and ultimately the sustainability of modern human civilization?

3) Where is non-knowledge situated and how does it act within knowledge architectures?

A related social implication of this research is to pose questions to ask if fascination with alternative energy may serve as a form of techno-denial to avoid facing the uncertain but thermodynamically inevitable end of growth in the combined human presence on our finite planet. Ninety-one questions from this work are summarized in the Appendix.

For instance, If wind and sunlight are free, why are wind and solar energy deployments so expensive, requiring billions in subsidies? Where do solar cell and wind turbine costs ultimately arise, if not from fossil fuels (via labor, materials, expertise, power conditioning, etc.)?

More broadly, we might understand the field of economics as a series of stories. Economics can foundationally be seen as an attempt to describe and predict details about how the bounty from the biophysical world – through extraction – is shared among human inhabitants. We typically associate aggregate growth with having more. But might one be able to propose just the opposite: that growth on a finite planet eventually leads to *less* for every individual? Less energy, less raw material, less ice cream? In these terms, wouldn't a decreasing human presence over time, aggregate degrowth, leave a larger average reserve of natural materials for every human, as well as for other life?

Summary of Chapter 2

This chapter begins to develop a material and semiotic analysis to identify potential co-constitutive power flows around moments of incommensurability within renewable energy and expansionist epistemes. That is, the apparent symbolism of renewable energy technologies may not always match the observed experience of their deployment and in some cases ahead we witness them in complete contradiction.

The absence or perceived absence of knowledge can maintain procedures and practices of scientific knowledge production, in manifestations of non-knowledge identified as strategic ignorance. These include “undone science,” which refers to scientific questioning that does not occur because the results could be inconvenient or dangerous for established interests, or could ethically oblige those interests to take actions that are financially or otherwise onerous. These concepts invite the idea of instrumental ignorance, which could indicate the potential utility for non-knowledge and may or may not relate to forms of ignorance that are intentional.

Knowledge may carry implications that are counter to the symbolic aspirations of researchers in a kind of semiotic jeopardy between the value of knowledge and the lack thereof. For example, Epstein (2012) details why the pharmaceutical company Merck avoided performing clinical trials on boys when it developed its adolescent HPV vaccine. This avoidance can’t be explained through an understanding of virology or the efficacy of the drug’s early animal trials – by those measures the vaccine might have been hypothesized as preventing cancer in both girls and boys. Instead, the company avoided male clinical trials because, if successful, the drug would be implicated in the prevention of anal cancer among male teens having anal sex – a far less desirable symbol for the company than the drug’s eventual subsequent launch as a “vaccine for cervical cancer.” This is a special kind of undone science – one we might characterize as a semiotically induced ignorance, of which we shall consider various formations ahead.

In many of the upcoming examples, we also witness an ignorance of financial inputs. These correspond closely with forms of ignorance about both material and energy inputs. Financial, material, and energy inputs are connected in the sense that monetary currencies ultimately represent a promise of natural material extraction and a financial economy can be seen as a coordinating story to divide up the obligations and benefits of that natural material extraction – all of which depends on flows of energy in the form of fuel, fertilizers, labor, an so on. And as a result, we are therefore dealing with forms of forbidden knowledge, those that can be existentially threatening.

We will also be exploring forms of *in situ* ignorance to the effects of technique in actual use, closely related to the concept of unintended consequences. These in turn often involve historical ignorance or institutional amnesia regarding past measurements, observations, and realizations. We will additionally focus on the role of assumptive ignorance in the development of intermittent energy technologies that are assumed to offset fossil fuels and question whether technological innovation can arise, persist, or even thrive through the service of such assumptions. Sometimes ignorance is professionally acquired or requires technical expertise. Consider Dewey's "occupational psychosis" (see Burke, 1954) or the concept of "trained incapacity" (see Burke, 1954) both related to Mannheim's (1936) "particular conception" of ideology. These generally hold that an individual's preconceptions can create blind spots, allowing past experience to detrimentally affect decision-making as conditions change. Also extending from a psychological dimension, is the work of Becker (1973) who aimed to clarify human actions and motives by shining a light on practiced self-deceit.

Specifically relevant to our energy society, and perhaps of interest to agnotologists, I will propose an extension of the phenomena of non-knowledge to include a class or an age – the epoch of an entire field – that shares an encumbering worldview. Similar to what Mannheim (1936) calls a "total conception" of ideology, this dissertation attends to not just one energy technology, or even the field of energy, but to an entire coproduced genre of belief. This potential conception presses us to think beyond simple considerations of *just* scientific data, or *just* economics, or *just* new energy technologies, or *just* environmental constraints, or just any single part of the broader regimes of energy production and use. Rather, we may consider the *relationships, communications, and shared beliefs* between the various constituents.

These considerations bring us out of the individual mind or group mindset and into what I will term a rhetorical genre of non-knowledge.

We will consider how the hegemonic consolidation around just one ecosystem impact measure – nominal carbon dioxide emissions – is possibly arbitrary and may constitute a form of ignorance through aperture and depth of field. By aperture, I am referring to a narrow focus on a single scale that consolidates discourse and capital flows into highly directional streams, which can in turn draw attention away from other scales. And by depth of field, I mean to point out the difference between nominal measurement of a practice, such as refueling an electric car, and the measurement of a practice *in situ*, such as a car that drives on asphalt, which requires bitumen, which requires petroleum exploration, which requires expertise, which requires universities, which requires cafeterias, and so on. We shall see ahead that problems of narrow aperture, low depth of field carbon emissions can rhetorically be solved, it would seem, by similar narrow aperture and shallow market driven solutions amenable to geopolitical capital interests. And in this brief example, we uncover our first opportunity for considering applied ignorance as a strategic asset in technological industrialization and in innovation networks more broadly.

Does the innate complexity in tracing energy inputs of technologies open a space to eventually draw upon this non-knowledge as a resource for justifying innovative activity? Smil (2017) states that "to talk about energy and the economy is a tautology" (p. 344). He explains, "every economic activity is fundamentally nothing but a conversion of one kind of energy to another, and monies are just a convenient (and often rather unrepresentative) proxy for valuing the energy flows" (p. 344). Admittedly, the value of fine art may not reflect the energy inputs that went into making it. However, the monetary value of a material or industrial commodity is a different case. How does the monetary cost of an industrial commodity correspond to the quantity of energy inputs used to pull it from the earth and process it into a usable form?

This research investigates whether the high cost of solar and wind energy technologies reflects a variety of intermediary costs such as labor, materials, fabrication, transportation, installation, and maintenance. Under current global economic arrangements, financing itself is additionally is closely linked to natural material extraction, which in turn is nearly entirely reliant on fossil fuels. Are there any costs of solar cells and wind turbines that are not ultimately reducible to fossil fuels? Such considerations could introduce a fossil fuel constraint to deploying solar cells and wind turbines that is presumably significantly below the limits posed by aggregate access to sunlight and wind.

In the U.S., the amount per kilowatt-hour spent on solar subsidies alone was larger than the purported retail cost of solar energy being claimed by the administration. Since subsidies can clearly make solar costs, and subsequently energy inputs, appear far lower than they actually are, why do researchers and journalists typically leave subsidies out of their cost reporting, or otherwise neglect to tally a full accounting of them? For solar thermal costs, specifically, the Department of Energy had been repeatedly publishing the same "dramatic-cost-drop" claim over the past three decades, every time as if it were a legitimately original milestone.

Despite their symbolic prominence in the clean energy movement, wind turbines and solar cells are not major components of what is globally counted as renewable energy, so why do environmental groups feature them as such? As has been anecdotally exemplified by Gibbs (2020), activists who may consider themselves to be renewable energy advocates may be shocked to discover that what is counted as "renewable energy" globally is roughly 70% bioenergy – the burning of living forests, plants, and animals for energy. Across the world, nature is being incinerated to meet climate targets ostensibly concocted to protect nature.

Summary of Chapter 3

This chapter analyzes how media framed certain aspects of the discourse surrounding energy solutions during the 2003-2008 global energy shock. What assumptions did journalists use to frame potential solutions to this crisis? Why did media focus more on energy *production* than on energy *reduction*? We can view only blurry snapshots but they have the advantage of capturing this energy ethos, which is an inseparable blend of factors including expectations, symbolic meanings, behavior, scientific authority, and psychological states.

Numerous mainstream scientific publications, policy papers, and news sources have published articles associating solar cells with beach sand in various ways. It is more difficult to find expert sources identifying that the primary starting material used for solar cell production isn't beach sand, or even crushed quartz "sand" for that matter, but coal. In fact, we can see this coal legacy in any solar array. Quartz is white; it is the coal de-oxidation step that yields polycrystalline silicon metal, which is what gives solar cells their black sheen. The observation that solar cells are borne from coal is a material observation that does not fit our generally accepted clean energy narratives and so there is potential for value in not seeing this relationship.

In this research we witness cultured forms of ignorance that are self-serving to their disciplinary fields and appear to be enabled at least by physical displacement (the material effects occur far from the lived experience of readers so it is difficult or impossible to check up on claims), disciplinary isolation (scientific and policy expertise is often separated from manufacturing expertise), moral caution erosion (descriptions may be technically correct and offer plausible deniability in context), and a prestige motive, which includes not just a profit motive but also an ego-protective denial that enculturates an emblematic sense that one is fighting the just war.

It becomes valuable to ignore that energy firms do not, and cannot, use solar and wind energy to create solar cells and wind turbines. Consider, for instance, the *chemical* role that coal plays in iron smelting for wind towers or the dense fuels required for extracting high-tech metals – these processes employ carbon, which cannot easily be replaced with just electrical power. Similarly, a kilowatt-hour of baseload power is incommensurate with a kilowatt-hour of intermittent solar or wind power, which require batteries or other forms of power conditioning, greatly affecting both their cost and lifecycle energy footprints – often by an order of magnitude. Still, experts routinely compare kilowatt-hour outputs of these power technologies side by side. This structural assumptive ignorance obscures a dangerous incommensurability of numbers facilitating political support for feed-in tariffs and mandates for intermittent power that reaps havoc on grids without enough of the expensive and fossil-fuel-intensive storage infrastructure to absorb it.

Readers are presented with the idea that the *priority* path to mitigating carbon is not through reducing consumption but through increasing production, using seemingly alternative means. We might assume that this is more or less acceptable so long as solar cells, at minimum, (1) offset fossil fuel use, and (2) produce significantly more net energy than is required for their construction and deployment. Media, as well as the vast majority of governmental and academic researchers *assume* that they do both. However, there is an emerging problem with these assumptions – there's scant material or theoretical evidence to support them.

Summary of Chapter 4

In publishing this case manuscript, I intended to discover through practice how an analysis that identifies a semiotic and material divide might be drafted and how, specifically, such an analysis be structured and contextualized. I also sought to incorporate potential roles of non-knowledge in the public understanding of electric vehicle development and use. I also intended to assess whether this mode of analysis showed promise to engage professional and lay audiences.

To begin, it was not the goal of the manuscript to evaluate the accuracy of the data within particular studies presented, nor did this work strive to demonstrate that supporters of the electric car were outside some mainstream consensus. Indeed, many electric vehicle researchers do claim that electric cars will produce environmental and economic benefits. Rather, I employed these works as data points in themselves that are worthy of comparison and exploration. I endeavored to expose the hidden assumptions that proponents of electric cars have made, the transportation options they leave out of their analysis, and why. I specifically outlined how research on electric vehicles was structured around just one ecosystem impact measure, nominal carbon dioxide emissions, which was introduced in Chapter 2 as being an example ignorance through aperture. We can see in the case of electric vehicle analysis how a narrow focus on a carbon emissions might consolidate discourse and capital flows into highly directional streams, which can in turn draw attention away from other scales of assessment. For instance, it is perhaps not surprising that researchers at the Electric Power Research Institute would appraise the cleanliness of an electric car differently than do the scientists at the National Academies. The researchers at EPRI studied the electric car's fuel cycle; those at the National Academies looked instead at public health impacts of the electric car's entire life cycle, including vehicle manufacturing. This case manuscript essentially argues that the answers we get depend on the questions we develop in the first place. It forms a critique not of nominal findings of electric vehicle research, but of the way these very questions are asked.

This analysis in effect exposes a type of shallow-depth-of-field ignorance, an ignorance that relies on one layer of effects to speak for the whole. For instance, the measurement of a single practice, such as refueling an electric car, versus a deeper consideration of that single process as one of many – a car that is refueled but also relies on asphalt for a driving surface, bitumen (and therefore petroleum exploration), which requires expertise, which requires universities, which requires cafeterias, and so on. An implication here, is the idea that when our questions deepen the depth of field enough, we may pass a threshold of perceived effects that can represent a tipping point of cumulative effects, which provide a platform for asking another round of much different questions.

To explore a deeper depth of field in this case, this manuscript attends to the larger transportation context. Even if electric cars gain in popularity, will we have invested billions of dollars to maintain an otherwise unsustainable transportation infrastructure? I proposed that perhaps the global fascination with electric vehicles has diverted our attention from other initiatives. A reminder of this came during the rush to extend electric-car subsidies, when the U.S. Congress largely gutted a highly successful Safe Routes to School program that was upgrading basic infrastructure for students and educators to walk or bike to school. Might the fact that schools hold bake sales to finance bike racks while car companies bathe in billions of public funds, be seen an important valuation of cleaner transportation, or an inglorious national embarrassment?

Drawing upon Chapter 2, we can see how in this case narrow aperture, low depth of field carbon emissions can come to be addressed through low aperture and shallow market driven electric vehicle solutions, which are congruent with capital interests. And in turn, we uncover an instance of ignorance becoming a strategic asset. I also unexpectedly discovered what might obvious in retrospect; when assessing depth of field, one never knows how far to stand back. I came up to the limits with this journal's editors. I attempted to incorporate the context of expanding human presence more broadly, but the frame was resisted by the editors of the journal, who were ultimately successful in removing any such contextual reference in its entirety. We might think that these larger concerns are unfair or irrelevant. In a world of eight billion people living in increasingly precarious times, might these be the tough questions that matter? What purposes do our solutions serve in constructively avoiding broader questions, which we do not care to discuss?

Summary of Chapter 5

This chapter characterizes hydrogen as a zombie technology, which might seem a bit harsh for those enchanted by the idea of a hydrogen economy, but in fact it has been called much worse by others – a pipedream, a hoax, or even a conspiracy. Nevertheless, these hasher concepts are too blunt to carve an intricate appreciation for the rise, fall, and resurrection of the hydrogen dream. A more nuanced rendering offers a peek into how diverse groups can coalesce around a technological ideal to offer it not only a life it would never have achieved otherwise but an enigmatic afterlife as well.

Even after hydrogen industry had collapsed, the reversal in fortunes didn't faze the public, scientific, or media enthusiasm surrounding hydrogen in subsequent years. Numerous government and university research budgets and disbursements, which had been pre-planned years prior, were still flowing. The nuclear establishment kept its hydrogen sights on autopilot. Car company PR and advertising departments still found it useful to present their fuel cell concept cars to the public. Journalists were evidently no savvier; the New York Times published a pro-hydrogen feature in 2009, in which it embarrassingly cheered on an industry and its associated product lines that had essentially been bankrupted years previously. The New York Times was not alone. Even though the hydrogen economy had died, its representatives were still busy posing for photo shoots, presenting at environmental conferences, speaking for the automotive industry, booking international trips, and eating at fine restaurants. The industry had even orchestrated a coup d'état in Congress to partially reinstate its funding. The hydrogen economy was not dead, but undead.

How was this possible? Why was the hydrogen dream so remarkably transcendent? Some might claim the hydrogen economy was never really alive to begin with; it surely never existed in any tangible way. Few people had ever seen a fuel cell vehicle, let alone driven one. Perhaps the hydrogen economy was nothing more, and nothing less, than a dream – a remarkably good one. In any case, we can think about the *in situ* ignorance surrounding the effects of hydrogen techniques in actual use, simply because the vehicles and support infrastructure had not been deployed to any appreciable scale. Such ignorance may have allowed people the luxury of imagining a world of abundant energy, a clean utopia where the only pollution would be water vapor, with enough material science mixed in to make the whole affair seem plausible. Various forms of ignorance about material and energy inputs, especially around the manufacture of hydrogen fuel, opened a welcome opportunity for critical environmental inquiry to be displaced by legitimized utopian impulses. In the case of the hydrogen dream, where large scale testing was impossible, demonstrations would suffice - the results of which were constrained through a series of legitimating articulations that were to a large degree market driven.

Others might say the hydrogen economy never died. After all, technologies are more than just physical artifacts – the gears, the batteries, the circuit boards. Technologies are a hybrid of intentions, interests, promises, and pretensions. Technologies are stories. If they were not, perhaps they would never catch on. The story of the hydrogen economy likely could not have been formed and fueled by just any single interest group, any single conspirator, or any single hoaxer as it were. As we have witnessed with other energy technologies, the hydrogen dream arose from a complex alignment of interests coalescing to synchronize a future narrative – one that featured selected benefits and additionally benefitted from various forms of non-knowledge about material inputs, side effects, and limitations.

Elected officials, many of whom had worked in the energy sector and were tacitly imbued with its productivist cant, stood to gain both donors and constituents by supporting clean hydrogen. Gas, coal, and nuclear industrial elites knew there was money to be made and valuable cover to be gained by articulating clean hydrogen visions. Academic researchers knew their work would be funded if it was framed as a national priority. Environmentalists could feel good about their work, while gaining public and monetary support by pledging allegiance to the clean fuel of the future. Automotive manufacturers saw opportunities for subsidies, profits, and most of all a clean PR cloak, which they could use to protect themselves from attacks by those who saw their industry as socially and environmentally destructive. And the greater public, primed with the verve of ecological modernization, was willing, perhaps even eager, to be convinced that hydrogen was, in fact, the future of energy.

Summary of Chapter 6

This chapter is the third of four chapters presented as case manuscripts and presses further to continue the thread started in Chapter 3 comparing the expectations for solar development with published data available leading up to and after the rise in fossil fuel prices and eventual global economic crisis in 2008. First, what were the specific benefits associated with solar cells during the period? And, second, how did these expectations map on to the published material understandings of these technologies at the time? Finally, how does this relationship form the questions we might choose to consider about solar technologies?

Collected and assembled into one material narrative, the field data as they were understood in large installations in California and Masdar City at the time of the 2008 crisis, become particularly intriguing in retrospect. The point here is not to label competing claims about solar cells as simply true or false, based on knowledge or on ignorance (we see they are a bit of both), but to question whether the materially borne attributes of these technologies at the time had manifested themselves in ways and to degrees that could have, in their own right, presumably validated solar photovoltaics as an appropriate means to achieve global environmental goals. Or, might we impart that there existed a degree of semiotically induced ignorance to the experience-based effects, costs, construction, and other material factors? Was such ignorance perhaps even necessary for the prioritization of these technologies over, say, energy reduction strategies?

What if we interpreted the powerful symbolism of solar cells as metastasizing in the minds of thoughtful people into a semiotic structure of belief? For instance, could we read these technologies as embodying lucrative forms of semiotically induced ignorance - shiny sleights of hand that allow oil companies, for example, to convince motorists that the sparkling arrays atop filling stations somehow make the liquid they pump into their cars less toxic? Might large fossil fuel companies choose to produce solar cells in an attempt to be seen as "cleaner" and "greener?" The bigger the sin, the greater the need for atonement? Further, we might question how politicians rely on the symbolic value of solar cells to boost their poll numbers in one hand while using the other to advance “economic growth,” jobs, and extractive industries that feed solar lifecycles. We have seen tension between the semiotic signifier and the signified, plausibly maintained through layers of non-knowledge, which may insulate symbolic impressions from the material attributes of energy technologies. This may manifest in more abstract structural forms as well. Consider that many homeowners are keen on upgrading to solar, but because the panels require large swaths of unobstructed exposure to sunlight, solar cells often end up atop large homes sitting on widely spaced lots cleared of surrounding trees – trees which could have offered considerable passive solar benefits. In this respect, the symbolic imperative of solar cells acts to obscure a the structural character of suburban residential construction that might otherwise be understood as an unsustainable car-dependent community model. This brings up a concluding question; might the promise of solar cells act to prop up a productivist mentality more broadly, one that insists that humanity can simply generate more and more power to satisfy expansion?

Summary of Chapter 7

This chapter explores the import of symbolic associations into the political process. What are the unintended consequences of wind turbine developments in context and what implications do these hold for the displacement of fossil fuels more broadly? We will also compare the nameplate capacity of solar and wind technologies to their actual production in context. We will see that the two valuations vary dramatically. What political opportunities does this variance create for selective knowledge in translating green symbols into actual policy actions?

Proponents frequently declare that wind power costs the same as fossil fuel power, but alternative-energy firms often aren't required to back up their temperamental products, which makes them seem less pricey than they are in practice. It is during the power conditioning steps that the total costs of wind power start to multiply. The inconsistency of wind power necessitates a dual system, the construction and maintenance of one power network for when the wind is blowing and a second network for when it isn't - an incredibly expensive luxury. This presents an opportunity to mobilize ignorance of energy quality through comparing varying qualities of power conversion, wind versus coal for instance, as if they are equivalent and interchangeable - a kilowatt for a kilowatt – when no basis for such a comparison could be formulated through a fuller knowledge of the difference.

It is not uncommon for a government to maintain two ledgers of incompatible expectations. One set, based on fieldwork and historical trends, is used internally by people in the know. The second set, crafted from industry speculation and "unconstrained" by history, is disseminated via press releases, websites, and even by the president himself to an unwitting public.

Here, we witness an unusually stark example of how ignorance can be valuably used instrumentally and in an applied manner to advance development of an energy technology, in this case taking it from the bench to the field on a large scale. Following the publication of the subject report of this chapter, hundreds of billions of dollars flowed into the wind power sector, to support everything from basic research to turbine installations. The use of DOE field data might very well have been inadequate to create the impression required in order to mobilize such funds.

Interested parties can advance technological industrialization by drawing upon valuable forms of contextual and strategic ignorance, which when applied, can mobilize non-knowledge into a credible form, such as a dataset, expert testimony, or government report. This credible form can provide a means of transfer of the subject non-knowledge to initiate funding, motivate public support, and mobilize implementation of the technology on a far larger scale than might have been otherwise realized.

Might subsidized wind turbines and solar cells, if they were to produce net energy, simply expand energy supplies and place downward pressure on prices? Might this in turn spur demand, entrench energy-intensive modes of living, and finally bring us right back to where we started: high demand and so-called insufficient supply?

Summary of Chapter 8

Fascinating peculiarities emerge from viewing renewable energy as a belief system, which might otherwise go unnoticed without an analysis that incorporates both the material and the semiotic, knowledge and non-knowledge. This dissertation endeavors to uncover instances of incongruence between semiotic valence and material observation in the development of energy technologies. And through those incongruencies explore the roles of various forms of non-knowledge in the maintenance of these incongruencies as a part of the innovative process. We considered how the current geopolitical prioritization of renewable energy technologies is a phenomenon that may not be adequately explained through perceived technical benefits alone.

This dissertation reflects upon how we might more deeply explore architectures of non-knowledge and non-knowledge transfer, specifically through symbolic relationships, in order to gain a better understanding of scientific claims about, and prioritization of, renewable energy innovation.

A material and semiotic analysis indicates that clean energy innovation may constitute a seductive anticipatory epistemology that draws from a cultured ecology of ignorance, which manifests consciously, unconsciously, or through some combination thereof. The ingredients of a solar cell, for instance, arise from a list of some of the most toxic and destructive industrial practices ever deployed by humanity. That the especially complex practice of natural material extraction and refinement for solar cell manufacturing, drawing together expertise from nearly every realm of industrial civilization accumulated over generations, is associated with simple and independent off-the-grid living, might alternately be understood as especially revealing about our capacity for self-deception.

This dissertation was not designed to research hoaxes or frame renewable energy technologies as such but has rather entertained if and how a framework of non-knowledge, whether strategic, trained, or otherwise accrued, could create rhetorical shelter for unwitting forms of group deception and uncoordinated dissembling. With a straightforward hoax, there is a hierarchy - those who "fall for" the hoax and those who "get" that the observed phenomenon is in some capacity manufactured. In introducing a reflexive framework of non-knowledge, these perspectives can merge into one. Non-knowledge need not be envisioned in hierarchical structures but it can function throughout flows of power involved in a sort of co-evolution as witnessed throughout this work's case manuscripts.

We might consider energy technology epistemes as collective and coproduced within a genre of storytelling, centrally informed through moments of amnesia about risks and impacts that are materially or temporally displaced. Professional use of the term "renewable energy" as a blanket stratagem of issue formation leads to a form of trained ignorance. We say "use renewable energy" instead of saying "dig up the earth, mine, dump the tailings, heat with coal, add heavy metals, add chemicals, and refine" or "burn the biology of the planet including animals, trees, plants, and seeds mostly grown with petrochemicals" – a process which few if any environmentalists would claim is renewable (see Dunlap & Arce, 2021). This example shows how language can serve as a kind of structural linguistic ignorance, as Richard Feynman implied in a 1966 lecture on how to identify pseudoscience; "There is a difference between the name of the thing and what goes on" (Feynman, 1969).

Clean energy isn't just a comforting story we tell ourselves. It is a comforting story we tell ourselves *about ourselves*. (see Geertz, 1973 definition of culture) Since we live on a finite planet, the system of ever-increasing expectations, translated into ever-increasing demand and resulting in again increased expectations, will someday come to an end. Whether that end is due to an intervention in the cycle that humanity plans and executes or a more unpredictable and perhaps cataclysmic end that comes unexpectedly in the night is a decision that may ultimately be made by the generations of people alive today. How might a better understanding of this predicament change the types of questions that various groups ask about energy?

While alternative energy technologies may mean different things to different people, we see that the heartiness of these notions manage to sustain a common identity across various disciplines. Beyond their manifest intended purpose of producing electrical power, various groups employ these symbolic technologies for their own varied purposes.

Just because a technology has attracted broad scientific support and investment doesn't necessarily mean that it conforms to the laws of physics. Through expanding our social scientific analyses to engage the material characteristics of energy technologies, as slippery as those are, we stand to shed light on prospective perpetual motion machines standing among the lineup of productivist strategies, or at least identify some unasked questions.

James Hansen, retired director of the NASA Goddard Institute for Space Studies, and one of the founders of the contemporary climate movement insists that "the notion that renewable energies and batteries alone will provide all needed energy is fantastical." He continues, proposing that "it is also a grotesque idea, because of the staggering environmental pollution from mining and material disposal, if all energy was derived from renewables and batteries. Worse, tricking the public to accept the fantasy of 100 percent renewables means that, in reality, fossil fuels reign and climate change grows" (Hansen, 2018). These high-level critiques from within the climate movement expose a disconnect between the promise of a renewable energy ideal and the lived experience of deploying energy technologies in an attempt to ward off climate change.

Solar cells, wind turbines, hydrogen reformation, and electric cars need not be seen as running parallel to carbon democracy but rather entirely within the same petro-neoliberal definitions of utility – more of the same by material measures, but this time dressed up in a semiotic achievement in its own right. Productivist environmentalists can enroll media to tattoo wind, solar, and biofuels into the subcutaneous flesh of the environmental movement. In fact, these novelties come to define what it *means to be* an environmentalist.

Throughout this analysis, we explore how renewable energy discourses in public science media, academia, and politics draw upon not only organized frameworks of knowledge, but also rhetorical genres of non-knowledge. Numerous actors draw upon both moments of visibility as well as invisibility to articulate paths these technologies ought to follow. First, diverse groups draw upon flexible clean-energy definitions and assumptive ignorance to attract support. Then they roughly sculpt energy options into more appealing promises – not through experimentation, but by planning, rehearsing, and staging strategic media demonstrations, a process that is itself a form of selective knowledge management. Next, lobbyists, foundations, and

PR teams transfer the promises into compelling stories, legislative frameworks, and eventually necessities for engineers to pursue. Green tech innovative processes rely on structural ignorance to factors conveniently difficult to quantify, assumptive ignorance involving offsetting fossil fuel use or decoupling, strategic ignorance of recorded but mutable factors, consequential ignorance of material unintended effects that remain hidden, and other forms of non-knowledge that are valuable assets to actors and institutions involved in capitalizing on innovation. What happens to our analyses of innovation if we frame innovators as skilled, or perhaps unwitting, conjurers of illusion?

Perhaps we have forged magnificent energy spectacles only to cast ourselves as climatic superheroes within the late stages of an illusion of abundance. If so, then these spectacles have come to protect us from questions about our own culpability in ecosystem decline. Green technologies seem to bypass worries of raw material scarcity since they exist in our minds apart from fossil fuel and extractive industry. We may invite them to ease our anxieties about increasing levels of CO_2 so long as we faithfully believe that they are carbon-free undertakings. But perhaps most centrally, clean energy spectacles protect us from considering our own aggregate growth, in consumption and numbers, which could not otherwise come to a peaceful end outside the storytelling of the current expansionist milieu.

Associated publications

This dissertation contains chapters and sections that have been published separately in various forms.

Chapters 1, 3, and 8 discuss the roles of latent assumptions and productivism immanent in building agendas around energy technologies. The foundation of this analysis was published in the peer review journal *Foresight* in an article entitled "Conjuring clean energy: exposing green assumptions in media and academia." Some discussions from these chapters were published in an interview with the *Bulletin of the Atomic Scientists* as well as an article published by *The American Scholar*.

The second chapter imports a discussion of unintended consequences, which was published in a similar form by the academic publisher Sage in a reference series entitled *Green Technology*.

The third chapter incorporates research that initiated with my masters thesis "Producing power: the semiotization of alternative energy in media and politics," and has been substantially updated and expanded in this work.

The subject of analysis in the fourth chapter is an article published in *IEEE Spectrum*, entitled "Unclean at any speed." The introduction of the fourth chapter details the context of the article.

Chapters 5 and 7 were published in the book Green Illusions, which contains numerous other chapters relevant to this work but are too extensive to include here. Chapter 7, the more largely updated of these two chapters here, relates to policy pieces published in *The Hill* and in my brief to the United States House of Representatives.

An earlier version of Chapter 6 was also published in Green Illusions but the chapter contained herein has been largely updated.

A list of these associated publications follows here and is also included in the bibliography.

Zehner, O. (2007) "Producing power: the semiotization of alternative energy in media and politics" University of Amsterdam.

Zehner, O. (2011) "Unintended consequences." In *Green technology*, eds Robbins, P, Mulvaney, D. and Golson, J.G., 427-32. London: Sage.

Zehner, O. (2012). Alternatives to alternative energy. *Bulletin of the Atomic Scientists, 68*(5).

Zehner, O. (2012). Five questions about the future of energy. *The American Scholar*, Summer.

Zehner, O. (2012). Nuclear power's unsettled future. *The Futurist*, *46(2)*, 17-21.

Zehner, O. (2012). *Green illusions: the dirty secrets of clean energy and the future of environmentalism.* London and Lincoln: University of Nebraska Press.

Zehner, O. (2012). Windy assumptions. *The Hill*, 12 December.

Zehner, O. (2013). Determination on extension of the wind energy production tax credit. Committee on Ways and Means, United States House of Representatives, 12 April.

Zehner, O. (2013). Unclean at any speed. *IEEE Spectrum, 50*(7), 40-45.

Zehner, O. (2013). Expensive green technologies aren't as clean as they seem. *IEEE Spectrum*, July 30.

Zehner, O. (2014). Conjuring clean energy: exposing green assumptions in media and academia. *Foresight, 16*(6), 567-585.

List of figures

longer publishes this side-by-side comparison and instead tabulates the figures in separate charts using different units of scale. Source: International Energy Agency, OECD, 2017 World Energy Outlook, used with permission.

Chapter 1: Questioning the productivist ethos[1]

Several years ago, a college of architecture asked me to evaluate student models for a proposed municipal building. The students eagerly displayed their green credentials. Some teams painstakingly topped their models with an elaborate origami of solar cells. Others incorporated wind turbines. Notably, however, only one team oriented their building to passively absorb and reflect the sun's rays and none had thought to capitalize upon prevailing winds for airflow and cooling. Were the students' high-tech solutions destined to haplessly supplement otherwise power-hungry structures? Were green gizmos blinding them to age-old architectural strategies for conserving energy? If so, these students were not alone.

Years previously, two researchers led a group of study participants into a laboratory, gave them free unlimited coffee, and assigned them one simple task. They spread out an assortment of magazines and requested that participants assemble them into collages that depicted what they thought of energy and its possible future. No cost-benefit analyses, no calculations, no research. Just glue sticks and scissors. Their resulting collages were telling – not for what they contained, but for what they didn't (Legget & Finlay, 2001).

The participants didn't address energy waste by featuring efficient lighting or insulation. They didn't choose to critique the factors that might be seen as underlying unsustainable energy use such as human expansion, inequality, overconsumption, or capitalism. Instead, they pasted together images of wind turbines, solar cells, and electric cars. When they couldn't find clippings, they asked to draw. Dams, wave-power systems, even animal power. They eagerly cobbled together fantastic totems to a gleaming future of power production. In general terms, this dissertation considers whether we, as scholars, energy professionals, writers, and policy makers, have done the same.

1.1 Considering growth, technology, and productivism

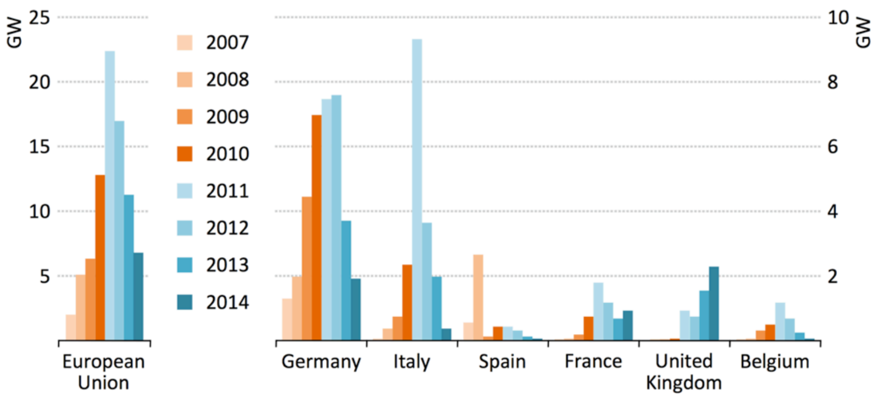
Gell (1988) posits that the essential techniques that in part constitute what we might call technology form a bridge

[1] Portions of this chapter published in "Conjuring clean energy" (Zehner, 2014)

between raw materials on one side and a goal-state on the other. Gell maintains such techniques are generally characterized by intelligent organization and exploitation of the given elements. The number and complexity of the steps that form this bridge may be simple and direct or complex and circuitous. Technological industrialization allows humans to use energy and natural materials at a rate far higher than the earth replenishes them (Capellán-Pérez, et al, 2019; Hall, 2011; Hueseman & Hueseman, 2011; Rees, 2004). This prowess, according to theorists of degrowth, peak oil, and related matters (Day, 2016; Heinberg, 2010; Murphy & Hall, 2011; Kunstler, 2007; Tverberg, 2012; Victor, 2008) essentially creates an illusion of abundance, of which we are presumably in the late stages (Ceballos, 2017; Dasgupta & Ehrlich 2013; Day, 2016; Ehrlich & Ehrlich, 2013; Hall, 2011, Ketcham, 2017). Meanwhile, scientists and researchers throughout many fields are generally in the business of finding ways to avoid technological failure and build upon technological success. Whether that success is truly a virtuous undertaking has been an open question for some time, and is of growing interest today given our precarious energy and economic predicaments (Ceballos, 2017; Gell, 1988; Kingsnorth, 2013; Mander, 1991; Tainter, 1988; White, 2009). What theoretical opportunities arise if we were not to immediately take these technological stratagems as part of a solution, but rather as a manifestation of a broader array of commitments?

Throughout academia, government, industry, and environmental organizations, alternative energy technologies, in particular, stand as prominent components in the storytelling surrounding sustainable futures. The prevailing consensus among the worlds most influential scientists maintains that 1) solar cells and wind turbines will offset some, or perhaps all, fossil fuel use, 2) these devices produce net energy apart from fossil fuels, and 3) the cost of these technologies is decoupled from the volatility of conventional fuel (IPCC, 2007; IPCC, 2011; IPCC, 2014). As such, the Intergovernmental Panel on Climate Change (2007, 2011, 2014) and the International Energy Agency (2013a, 2019, 2020), along with numerous scholars, business leaders, and politicians claim that green tech will become more competitive, or even thrive, as regions shift away from fossil fuels due to choice or scarcity. But at least so far, this has not borne out in regions experiencing contraction. In 2013, Spain's solar industry, which grew to become a leader in previous decades, estimated that 44,000 of the country's 57,900 solar installations risked bankruptcy amidst a tightening of national economy (Nikiforuk, 2013). Spain's solar industry was the first in Europe to peak, collapsing in 2008 during the global economic crisis (IEA, 2016). Solar installations in France, Italy and Belgium peaked in 2011 and Germany peaked in 2012 (IEA, 2016).

Figure 1.1: Deconstructing the peak of Europe's solar movement – new annual capacity added (© International Energy Agency, OECD, used with permission[2])

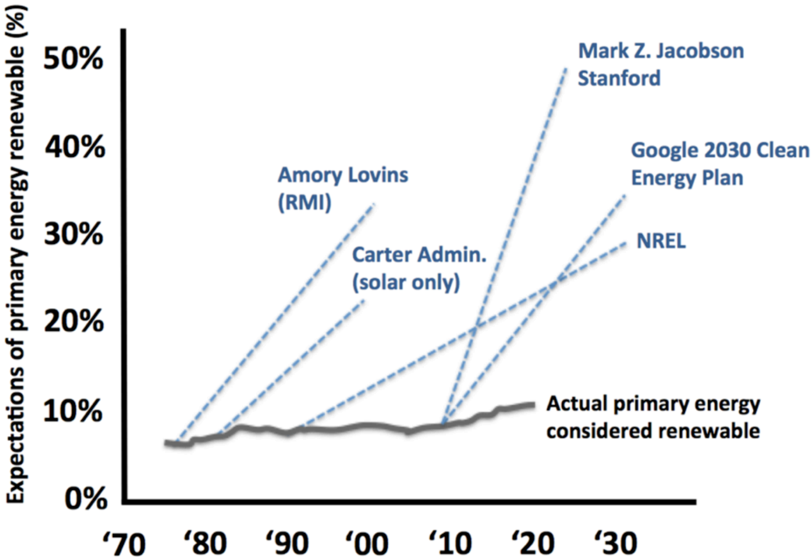


When Greece's economy collapsed following a debt crisis in 2009 and fossil fuels became less affordable, consumers did not demand solar cells. Nor, in the midst of energy scarcity, could the government afford to erect wind turbines, install wave power systems, or shift the vehicle fleet over to electric cars. These perceived solutions were expensive; their constituent industrial commodities increased in scarcity along with the fossil fuels used to produce them. Instead, many Greeks did what other groups of energy-stressed humans have done preceding civilizational collapse; they grabbed their axes, went into the forests, and chopped down their trees (Bologna & Aquino, 2020; Michopoulos, Skoulou, Voulgari, Tsikaloudaki & Kyriakis, 2014; Perlin, 2005). These are sobering hints into why energy supplies,

[2] © OECD/IEA 2015 World Energy Outlook, IEA Publishing,. Licence: www.iea.org/t&c The associated research does not necessarily reflect the views of the International Energy Agency.

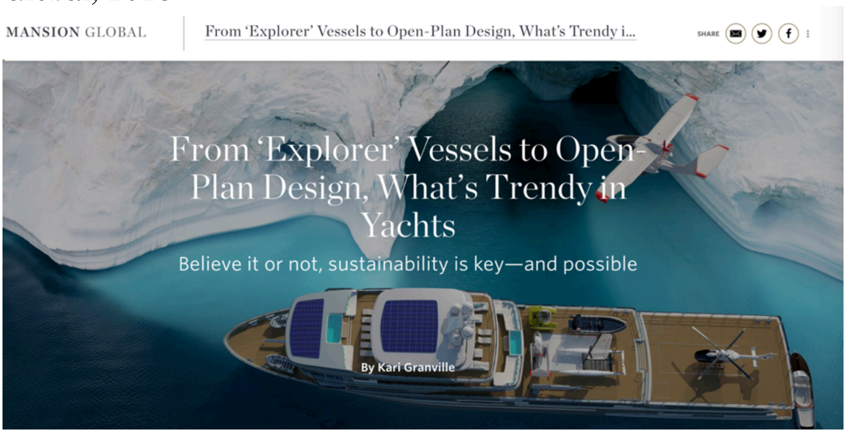
economy, and energy narratives are reflexively interlinked and how clean energy expectations (figure 1.2) may not mesh with lived experience during periods of energy volatility or precarious access to fossil fuels.

Figure 1.2: Expectations for the share of US primary energy use from renewables greatly exceed actual renewable energy share (2021). Sources: EIA, Amory Lovins, Rocky Mountain Institute, Carter Administration, National Renewable Energy Laboratory (NREL), Google 2030 Clean Energy Plan, Mark Jacobson, Vaclav Smil, via JP Morgan



These contemporary histories of professed green technologies bring us to question whether belief in clean tech could be associated not with civilizational success, but rather with perpetuating an illusion of abundance – perhaps to great detriment. The overarching inquiry to start off this work might at first seem counterintuitive or even implausible but may become more palatable moving ahead. We may not answer this question here but it serves as a launching point to consider some more specific questions ahead, principally: does the genre of climate, sustainability, and energy abundance storytelling draw upon people's concern for our planet in the service of perversely intensifying its destruction?

Figure 1.3: In this headline it is perhaps straightforward to identify how sustainability narratives and beliefs might be useful for the ultra-rich in the pursuit of the most extreme forms of consumptive destruction. Is it reasonable to consider such phenomena in less grand formulations? Does the genre of climate, sustainability, and energy abundance storytelling draw upon people's concern for our planet in the service of perversely intensifying its destruction? Source: Mansion Global, 2018



With a few exceptions, humans have historically considered growth to be good, leading to more material wealth for more people – especially those clever enough to have been born into the right family (Graetz, 2013). But is the story of growth only conceivable within an illusion of endless abundance? Overall, economic growth paired with human expansion depletes natural materials, reduces biodiversity, and intensifies numerous other global risks, presumably placing more souls in jeopardy of a rocky contraction were one to occur (Capellán-Pérez, et al, 2019; Ceballos, 2017; Hall & Klitgaard, 2011; Hanauer, 2013; Ketcham, 2017, Shragg, 2015).

We typically associate aggregate growth with having more. But might one be able to propose just the opposite: that growth on a finite planet eventually leads to *less* for every individual? Less energy, less raw material, less ice cream? In these terms, wouldn't a decreasing presence of people over time with aggregate degrowth, leave a larger average reserve of natural materials for every human, as well as for other life? Where might such considerations lead our notions of equity? As long as the story of growth seems plausible to enough people, then growth may well continue. For a time. But to the extent that growth continues, might we view this as human civilization extending a gangplank out over a more abrupt decline, an ultimate form of Beck's (1992) "risk society?" Modern energy systems deliver more than just utility; they symbolize modernity, excitement, wealth, and power (Nye, 1990; Nye, 1999). Our language describes how people "recharge their batteries," "get their wires crossed," and even experience "short circuits." Our symbolic preconceptions of energy shape what options we consider as well as those we cannot see. Many of us hinge our civilization's future on the fundamental promise that innovations such as alternative energy will rescue us from potential ecological crises and fossil fuel shortfalls. Does this focus obscure other options? Furthermore, what risks might this system of belief create?

1.2 Research questions

If we entertain that cultural conceptions of energy can play a central role in the construction of the built energy infrastructure, both theoretically and physically, then to even approach the broad questions above requires first asking some more specific questions about sustainability narratives and material effects. For instance, the rather bold considerations above open the door for this initial research question:

What, symbolic dispositions of energy technologies are emanant in the public realm involving sustainability and in what ways do these appear to come into alignment or discordance with the measured or otherwise observed experience of these technologies in practice?

This initial question contains both a semiotic and a material component and therefore presents certain methodological challenges. First, how can we even hope to identify and conceptualize symbolic impressions of energy technologies such as solar cells and wind turbines in the public realm? Then, what symbolic associations and expectations are associated with renewable energy technologies? And finally, in what ways do these symbols and expectations appear to correspond with what we know of the actual deployment of these technologies in situ? The inherent limits and particularities of these questions will be addressed ahead. Chapter 3 will provide the basis for analysis and some initial insight into these questions.

Through the opening stages of research into the material and semiotic comparison above, a second epistemological research question becomes apparent, involving a plausible emerging discordance between symbolic versus measured experiences of the energy technologies at hand. There appears to be a gap between the expected and experienced outcomes of these technologies *in situ*, which implores an explanation or at least an inquiry into the epistemological bridge over this gap. It also becomes apparent that the more revealing question might not be phrased in terms of knowledge but the absence or apparent absence thereof. And finally, what seems of equal interest are potential moments of non-knowledge situated within knowledge frameworks and the resulting interactions between knowledge and non-knowledge in innovative work. As a result, the second research question for this dissertation arises organically:

In what ways do forms of non-knowledge - such as strategic ignorance, assumptions, trained incapacity, misdirection, and denial – contribute toward binding together otherwise incommensurate systems of belief about renewable energy and ultimately the sustainability of modern human civilization? And, where is non-knowledge situated and how does it act within knowledge architectures?

Now, to be clear, the civilizational aspect of this question is clearly overreaching and will not be answered in this research but is included in order to situate the more focused inquiries into the potential forms of non-knowledge at hand. These two research questions set the stage for several sub-questions, for which each is afforded a chapter. Chapters 1 through 3 prepare a theoretical framework to situate the case manuscripts in Chapters 4 through 7. Chapter 8 presents a discussion and concluding thoughts. The following sections of this chapter will consider the implications of these chapters and the methods involved in more detail.

Chapter 2 introduces the concepts of strategic ignorance, trained incapacity, misdirection, denial, and other forms of non-knowledge and questions whether they are contributory, or even imperative, in binding together otherwise incommensurate systems of belief about renewable energy and ultimately the sustainability of modern human civilization. This work deploys agnotology as a tool more than it engages with underlying theoretical agnotological framing but here too is a methodological conundrum. Specifically, how can we attempt to determine if something, knowledge in this case, is missing? How can we hope to investigate something that is potentially not there? These questions will be explored in Chapter 2.

Starting in Chapter 3 this work considers the symbolism of renewable energy in public science media. What symbolic inclinations might we be able to identify in energy technology discourse? If we accept that cultural conceptions of energy play a central role in the co-construction of the built energy infrastructure, then could a culture of productivism be situated as an underlying force to assess structures of non-knowledge in political, business, institutional, and scientific discourse? Can researchers, environmentalists, politicians and businesses draw upon non-knowledge as a form of green capital?

Chapter 4 is structured around the following sub-question: What can be learned from initiating a public and professional dialog that proposes a semiotic and material divide in green tech? What can be achieved through acknowledging a potential role for non-knowledge within green tech trajectories? How can such an analysis be structured and contextualized? What impacts might a consideration of non-knowledge have on the public understanding of energy technologies? Does this mode of analysis hold the potential to engage professional and lay audiences?

Chapter 5 follows the rise and fall of the idea of a hydrogen economy that took place during the 2000s and asks in general terms: What is material semiotic discordance and what does it look like when it occurs? More specifically, in what ways did symbols of the hydrogen dream become involved with action and material effects within the technological episteme? Did symbolic elements between various actors align, did they remain separate, or did some other organization of semiotic interests manifest? When the discordance, or gap, between the symbolic and the material became too great to sustain, what was the semiotic fallout for the hydrogen dream?

Chapters 6 and 7 continue the analysis to focus on solar photovoltaic and wind turbine development. How, specifically, are green tech agendas crafted around selective knowledge about known consequences? Chapter 6 continues a thread started in Chapter 3 comparing the expectations for solar development with published data available leading up to and after the rise in fossil fuel prices and eventual global economic crisis thereafter. What were the specific expected benefits associated with solar cells during the period? And, how did these expectations map on to the published material understandings of these technologies at the time? Finally, how does this relationship form the questions we might choose to consider about solar technologies?

Chapter 7 considers the import of symbolic associations into the political process. What are the unintended consequences of wind turbine developments in context and what implications do these hold for the displacement of fossil fuels more broadly? This chapter also compares the nameplate capacity of solar and wind technologies to their actual production in context. The two valuations vary dramatically. What political opportunities does this variance create for selective knowledge in translating green symbols into actual policy actions?

Chapter 8 returns to the two principle research questions posed above and reaches to incorporate some overarching questions informed through the chapters as a whole: Does strategic ignorance play a role in green technological expectations, symbolism, and ultimately clean tech trajectories? If so, how does non-knowledge arise and function in material semiotic relations? At what stage and to what extent are these relations a part of innovation? Through what rhetorical, institutional, political, and social mechanisms does non-knowledge operate in green tech innovation?

Together, these groupings of questions constitute the arc of this dissertation. Throughout the manuscript there are other questions that will arise. Some of these subsequent questions will be addressed in part and others will be left for future research as explained in the methods sections that follow.

1.3 Originality, objectives, and social implications

This dissertation does not take at face value scientific claims that renewable energy strategies such as solar cells are renewable, a solution, or even partial solution, to climate change, or even that they yield net energy at all during their lifecycles in the context of their deployment. Instead, through investigating and comparing both the materiality borne through the practices of what is classified as renewable energy as well as the semiotic valences of these energy practices, this work simply aims to uncover unasked questions and perhaps theoretically necessary questions that would need to be answered in order to stake certain claims and assumptions typically accepted about renewable energy and green tech solutions.

An academic objective here is not to produce a list of findings, but rather to produce a collection of questions and material semiotic perspectives from which to ask better questions about energy technologies *in situ*. We typically understand the value of question formulation as a driving force behind scientific and technological development but we may additionally consider the potential for economic, political, and scientific value in *not* asking questions as well.

Related to this work's attention to the material aspects of energy technologies, Hall and Klitgaard (2011) create an appeal to economists, arguing that economics as a discipline must better account for the biophysical world. In fact, we might understand the field of economics as a series of stories. Economics can foundationally be seen as an attempt to describe and predict details about how the bounty from the biophysical world – through extraction – is shared among human inhabitants. Hall and Klitgaard describe that the field of economics developed within a period of human history wherein only about 1% of energy supplies were in turn used to dig up more energy. Currently such energy unearthing can require percentages well into the double digits and those costs of exploitation, in energy and monetary terms, are growing. Ultimately, in order to sustain the physical and social components that constitute the modern world, according to Hall (2011) and Day (2016), the multiple of energy-return versus energy-invested would need to be at least around 5:1 to 10:1 (i.e. for every barrel of crude oil that oil company uses to fuel its operations, the company would unearth 5 to 10 barrels of oil). Energy technologies such as solar cells and wind turbines do not appear to come close to this energy return on investment, that is, if they provide positive net energy at all in practice (Ferroni & Hopkirk, 2016, Tverberg 2020) - more on this point to come. If wind and sunlight are free, why are wind and solar energy deployments so expensive, requiring billions in subsidies? Where do solar cell and wind turbine costs ultimately arise, if not from fossil fuels (via labor, materials, expertise, power conditioning, etc.)?

A consideration here might initially be posited in terms of whether groups of environmentally-minded people, conceptual structures, and practices are inculcated into a form of what Schwarz-Cowan (1983) terms "cultural obfuscation" (p. 4), wherein a certain cultural prejudice can obscure the material effects of a technological or industrial practice. As an example, Schwarz-Cowan (1983) argues that the public understanding of technological industrialization is principally understood as happening outside the home. Schwarz-Cowan (1983) highlights that men leave home five times per week to stamp time clocks for full-time jobs in factories under contractual arrangements that we may associate with technology and industry. "The popular imagination goes one step further; industrialization is conceived as being not just *outside* the home but virtually in *opposition* to it (p. 4)," Schwarz-Cowan writes, but "in reality kitchens are as much a locus for industrialized work as factories and coal mines are, and washing machines and microwave ovens are as much a product of industrialization as are automobiles and pocket calculators" (p. 4). Schwarz-Cowan exposes a conceptual frame of ignorance about the material aspects of a technological ideal which extends beyond the bounds of class or profession and rather persists within a frame of gendered semiotic classification. The blind spots that manifest within our gendered preconceptions are a matter of great interest among scholars as much as among comedians. However, what we take for granted today in these narratives would have constituted an implausible basis for research, or a joke, a century or even a half century ago.

In coming chapters, this dissertation explores whether something similar is occurring with energy technologies that are considered to be "renewable" or "clean." However, implying that there is an obfuscation on the stage could implicitly impart that there is some underlying reality which it obscures. Staking truth claims in an effort to access to this underlying reality becomes problematic from a scientific and philosophical perspective. To be clear, it is not the purpose of this work to separate facts and values of nature into separate or opposing columns, pitting one against the other. Latour (2004) enters into Plato's *Allegory of the Cave* in order to reveal the danger of adopting a science of facts that is separate from the values of its practitioners. In pursuing the material account of energy technologies ahead, this research humbly follows *episodes of discordance* between symbolic conceptions and observed material attributes principally through 1) comparing claims by renewable energy advocates against their own facts and figures, occasionally transformed through straightforward multiplication or division, and 2) elucidating potential internal contradictions within the renewable energy belief system a priori. The product is a hybrid - part theoretical analysis and part empirical – a pulling-apart more than a putting-together – something to chew on more than something to swallow. Consider, for instance, that environmentalists once stood against batteries, but when it comes to the largest battery-powered gadget ever created, the electric car, mainstream environmentalists cannot jump fast enough from their seats to applaud it. Rather than simply writing about this phenomenon in the pages of this dissertation as a simple subject of theoretical inquiry, I do something slightly different. I assembled what social scientists might call a material and semiotic analysis but in a language appropriate to a mainstream technical audience, and submitted this analysis to the top-read journal of the very discipline of electrical engineers who build and profit from electrical vehicle development. The journal published the article – not hidden in the depths, but as a cover feature - which included an image of an electric car atop a large pile of coal, a violation of the intoxicating symbolic association of electric cars with something separate from fossil fuels. The fallout from this heretical move was tremendous and highly controversial, ultimately resulting in a published analysis that is itself a potential object of analysis (see Chapter 4, which comprises both the original article and an analysis of its reception).

A principal aspect of this method is to present potentially uncomfortable questions about the viability of alternative energy technologies, which are scarcely addressed within media and academia. The attention to media in particular reflects a potential impact of this work to engage journalists in new forms of questioning to potentially enrich the public understanding of energy technologies. For instance, Chapter 3 will identify and graphically illustrate differences between media expectations for renewable energy *production* versus energy *reduction* strategies. This research indicates that in contrast with their reporting on *energy reduction* technologies, journalists tend to write about *energy production* technologies using 1) more character-driven storytelling, 2) about twice the amount of promising language, and 3) many more references to climate change and energy independence. We will ask whether and in what ways these observations might in some limited way help to illustrate a pervasive energy production ethos, a reflexive network including behaviors, symbols, expectations, and material conditions. The subsequent chapters will then contrast green energy expectations with material factors to develop unasked questions involving, for instance, urban myths (e.g., solar cells are made from sand), assumptions (e.g., alternative energy is of comparable quality to fossil fuel energy and can offset its use), instrumental ignorance (e.g., solar cost drops reflect Moore's law), trained incapacity (e.g., solar and wind energy is low- or zero-carbon), and related agnotological inquiries. A related social implication of this research is to pose questions to ask if fascination with alternative energy may serve as a form of techno-denial to avoid facing the uncertain but thermodynamically inevitable end of growth in the combined human presence on our finite planet (Hickel, 2018; Ketcham, 2017; Seibert, 2020). Ninety-one questions from this work are summarized in the Appendix.

Ultimately, this dissertation's originality stems from its new, unasked, questions regarding the expectation that alternative energy technologies can replace fossil fuel and lead to a sustainable human civilization. These and related questions introduced throughout the text will not necessarily be answered here, but will hopefully be of use to journalists, policymakers, researchers, and students in framing a new critical environmentalism.

1.4 An interactive mixed method

Let us first address the methodological conundrum introduced above; that is, how can we attempt to determine if something, knowledge in this case, is missing? How can we hope to investigate or determine if something is potentially not there? This would be an arduous task to say the least, not to mention theoretically problematic. Instead, the this research employs a far less ambitious and more restrictive method. Instead of looking for the absence of knowledge, this research seeks to identify potential openings or instances of non-knowledge within the subjects at hand, to consider how non-knowledge might work in those moments specifically, in the service of subsequently asking better or at least more interesting questions in the future. Analyzing potential moments of incommensurability introduces a type theoretical perspective akin to bayesian probably sampling. Compared with parabolic fitting, Bayesian methods consider a series of probabilities that an event might be occurring rather than attempting to capture an event directly as it occurs. The advantage of a Bayesian perspective in mathematics is that it can reveal phenomena hidden in noisy data that a straightforward parabolic method might overlook or misidentify.

This dissertation relies on a mixed method approach, detailed below, to trace these moments, principally including 1) site visits to energy technology sites in the US and Canada, 2) interviews with political, industry, and activist representatives, and 3) public science media analysis including cosine-normalized word matrix visualizations. This research seeks to identify and analyze potential moments of incommensurability between the material and semiotic aspects of the energy technologies at hand. I pressed on these potential moments of incommensurability, becoming more familiar with the literature, including scientific, professional, and public media, to create what will serve as vignettes throughout the chapters of this dissertation. In accordance with the scholarly and social research objectives for this work, these vignettes are not presented as findings per se but as platforms from which to develop different types of questions about the energy technology episteme.

In order to say something about the materiality of these technologies requires a methodical and deep familiarity with the topics at hand, which I attempted to achieve not only through extensive reading and research but also interviews and site visits. These occurred in an iterative form, beginning with initial research into symbolic claims and valances, followed by site visits and interviews, followed by more specific research into the material attributes of those site visits, followed by repeat site visits. In the process of this work, I travelled to Washington, DC to interview United States Federal Energy Regulator James J. Hoecker who served during the Clinton presidency from 1993-2001 as well as United States Federal Energy Regulator Philip D. Moeller, who served during the Bush and Obama administrations from 2006-2015. I also attended an annual conference organized for electrical grid operators and interviewed industry representatives and consultants to the industry. I revisited Washington, D.C. to attend a televised national

Earth Day celebration that was advertised as running on 100% solar energy to find that while the festival did have a large solar array prominently on display, the festival was not even hooked up to it. Instead, the entire festival was actually being powered by large biodiesel generators operating behind a number of security fences situated around the Washington Monument where the event was taking place. These interviews and visits informed my research and understanding of solar and wind technologies in practice, covered in Chapters 6 and 7.

I attended locally-focused environmental demonstrations in Ohio, Pennsylvania, Maryland, Illinois, and California; I interviewed a number of activists and environmental leaders at each site. I attended environmental education and training seminars held by organizations that are the subject of the upcoming analysis in North Carolina and California. I interviewed about two dozen solar industry representatives from various parts of the solar industry as well as a representative from the German Government who specializes in international economic cooperation between the United States and German solar industries. These visits mainly informed my research in Chapters 2 and 3.

I visited the Solar Electric Generating System in the Mohave Desert once during its operation and once again during its subsequent dismantling for replacement. I also visited the ruins of the earliest large-scale solar arrays built in California, which are now enormous sandy dead zones, devoid of the ancient life characteristic of the surrounding desert.

Figure 1.4: An aerial view of an abandoned solar array in the Mohave Desert. The site, which sits behind a tall chain link fence, is a massive windswept landscape nearly devoid of life. An array of animal and plant life including ancient creosote bushes, thousands of years old, once covered this solar energy dead zone. Plans for a renewable energy future call for tens of thousands of such clearings to build arrays that will last about 10-30 years. Image credit: Google

I also made four trips to the largest solar array in the world in Ivanpah, California – once during construction, once during testing, and twice during operation, including during a wind storm when I witnessed the collapse of many of the large mirrors in the array. I attended hearings held by the California Energy Commission on the Palen solar array project in California before it was constructed and visited and photographed the desert landscape before it was cleared for the project. I explored about two dozen utility-scale solar array sites including the Apple Data Center in Maiden, North Carolina, the site of a large solar array for which a forest and watershed were cleared. I also visited the small section that remains of that forest. On that trip, I went to the Spruce Pine mine, where a geologically rare form of quartz necessary to construct vessels used in solar cell and microelectronics is mined. I interviewed local residents including two men who had worked in the mines. I visited Rio Tinto Group's Kennecott Bingham Canyon Open Pit Copper Mine outside Salt Lake City, Utah, considered the largest man-made excavation in the world. Another large mining site of note that I visited was the Mountain Pass rare earth mine near Mountain Pass, California which once supplied most of the world's rare earth elements, including those used for solar, wind, battery, and electric vehicle applications. A rare and endangered Joshua tree forest was felled to build the sprawling facility and its associated tailing pits. The mine was subsequently shut down due to environmental contamination including multiple radioactive waste spills. I measured radiation levels outside the site using a high-sensitivity Geiger counter. These visits to the American southwest principally informed my research into claims about solar costs and carbon neutrality in Chapters 2 and 6.

I explored numerous wind farms in Iowa, Michigan, and California including two visits to the large San Gorgonio Pass Wind Farm outside Palm Springs, CA. I was also afforded the opportunity to travel up inside a wind turbine in Vancouver, British Columbia and observed a shipping terminal and land transport of wind turbine blades and nacelles in and around northern Indiana and Michigan. In addition, I visited the sites of new natural gas plant construction and replacement projects in Nevada, Iowa, and North Carolina. These visits informed my research in chapters 2 and 7.

I took extensive photographs, videos, and notes at each location, which in its entirety is too much to cover in these pages. These visits intimately informed the questions posed and threads explored in this work, however, in moving forward with these questions, this work incorporates published research in the public domain.

The story of renewable energy in particular is an alluring one. It is powerful as an organizing principle of activism and capital. But beyond the physical attributes of these technologies that I witnessed in the field, what else does the story of renewable energy do for us on an intellectual and emotional level? How does it protect us? How does it shape our conceptions of ourselves as moral citizens? And, how does it influence the questions we even think to ask? Chapters 2 and 3 introduce the intellectual framework for this dissertation. This analysis considers potential implications for the framing environmental discussions in public science media through an analysis of the literature during a period of intense focus on rising energy costs preceding the 2008 global economic crisis. As reviewed in more detail in Chapter 3, from 2003 to 2008 when petroleum prices tripled, media coverage of energy rose to stratospheric highs. LexisNexis, the media database studied for this research, accrued a corpus of roughly 50,000 articles on energy written over those years. For every doubling of oil prices, media coverage of solar, wind, and biofuels shot up 300%. By contrast, media coverage of strategies associated with energy reduction – LED lighting, public transit, and building insulation – remained comparatively low over the same period, averaging just a 25 percent increase. To explore these differences I narrowed the corpus to mainstream articles published during the initial three years of the energy shock that covered solar cells, understood as an energy *production* technology, and light-emitting diode (LED) lighting, understood as an energy *reduction* technology. I argue in Chapter 3 that this is an appropriate specificity since both technologies are high-tech devices that were commercialized in the 1960s, exposed to oil shocks, and promoted for military, space, and consumer applications. They co-exist but their developers compete for limited funding and media attention. Whether these two technologies actually achieve their presumed purposes in the real world is a far more complex assessment due to considerations such as rebound effects (Herring, Sorrel, & Elliot, 2009) and is not a central focus of this work.

Through multiple close readings, I discovered three distinct differences between the way journalists wrote about these technologies. In addition to a description of my findings, I built semantic maps to roughly display these three prominent themes using concordance, statistical, and visualization programs that employ force-directed placement methods to arrange frequently-used words into relational clusters.

As explained in more detail in Chapter 3 (see 3.1), I used TextSTAT to build a word frequency list from the articles. By filtering to the most common words in each set of articles, the difference in size of the two databases became roughly normalized. I used this normalization technique for three topical word lists to create a cosine-normalized word matrix for each set of articles. I imported this matrix into the visualization tool Pajek which allowed for further reduction by displaying only the most central words and links in the network and scaling the dataset, improving the visualization of the matrices. I outputted the maps using a Kamada-Kawai free association, a so-called force-directed placement method for undirected graphs, which arranges formless distributions of points into relational clusters, i.e. shows the relations between words as they are used in the articles. The resulting maps illustrate the most common words associated with our selected technologies around three themes: technical description, promises, and potential to mitigate climate change.

The maps resulting from this limited method and illustrated in Chapter 3, show the most common words associated with the selected technologies around three themes: 1) technical descriptive language, 2) future promises, and 3) potential to mitigate climate change. Throughout this semiotic analysis, material considerations are interjected, not in the service of evaluating such material knowledge, but in the service of provisionally destabilizing the symbolic associations at hand so they may be seen from a different perspective. Chapters 4 through 7 extend this technique to situate the concept of renewable energy with its material attributes, the inner workings of which we could only hope to partially uncover through the iterative method including site visits detailed above. These later chapters are therefore presented as affiliated case manuscripts grounded within, and set in motion for, the purposes of advancing the theoretical frames proposed in the first three chapters. The final chapter draws them together with some concluding thoughts, questioning for instance whether symbolic associations with energy technologies and other proposed solutions can act with hegemonic authority. This method, as limited as it is, has the benefit of showing a perspective that, once seen, might be difficult to un-see. In other words, the value of this method is in introducing perspectives rather than staking claims. If we are indeed fish swimming in water then jumping above the surface for a fleeting moment might be our only chance to see the liquid medium. These case manuscripts end up troubling the accepted narratives about renewable energy in the process explore the roles of assumptions, non-knowledge, and symbols as to potentially be of service to those practicing green epistemology.

Chapter 2: On the other side of knowledge

The forms of non-knowledge are as varied as the forms of knowledge and, as might be expected, these forms overlap and intertwine so thoroughly that they typically cannot be neatly separated for analysis. As an integral part of its material semiotic approach, this dissertation both implicitly and explicitly explores the roles of various forms of non-knowledge in the scientific, political, and public understanding of renewable energy technologies. Essentially, this work questions whether potential genres of non-knowledge may help to define conditions of possibility for renewable energy. In this sense, are such genres constitutive of an existing energy infrastructure that otherwise might not have developed in the way that it has? Knowledge and practices are frequently taken as factors co-evolving within and through technological systems including energy infrastructures (Hughes 1987; Nye 1990, 2006). Why not consider the role of non-knowledge as well? This dissertation develops a material and semiotic analysis to identify potential co-constitutive power flows around moments of incommensurability within renewable energy and expansionist epistemes. That is, the apparent symbolism of renewable energy technologies may not always match the observed experience of their deployment and in some cases ahead we witness them in complete contradiction.

The upcoming chapters explore whether and how non-knowledge can be inculcated into power relations, creating and maintaining subjectivities. In practical terms, we may see these subjectivities manifest within individuals who see themselves as clean energy citizens, carbon free drivers, or in other roles of environmental champions through a process that Fairclough (2014) characterizes as "people coming to 'own' discourses, to position themselves inside them, to act and think and talk and see themselves in terms of new discourses" (p. 208). In chapters 4 through 7, this work intends to import material factors of renewable energy technologies into the dialectical relationship, specifically analyzing solar cells, wind turbines, electric vehicles, hydrogen storage systems, and the associated technological representations of how these materials act and push back, as well as exploring imaginaries about how they may, or should, act in the future (see also Hornborg, Cederlöf, & Roos, 2019).

2.1 Agnotology in sustainability storytelling

The absence or perceived absence of certain forms of knowledge can yield political capabilities which might otherwise be unavailable, such as with the formation or preservation of certain policies as well as their associated meanings within political constituencies (Yanow, 1996; McGoey, 2012). The absence or perceived absence of knowledge can maintain procedures and practices of scientific knowledge production, in manifestations of non-knowledge identified as strategic ignorance (McGoey, 2012). These include "undone science," which refers to scientific questioning that does not occur because the results could be inconvenient or dangerous for established interests, or could ethically oblige those interests to take actions that are financially or otherwise onerous (Frickel and Vincent, 2007). These concepts invite the idea of instrumental ignorance, which could indicate the potential utility for non-knowledge and may or may not relate to forms of ignorance that are intentional.

Knowledge may carry implications that are counter to the symbolic aspirations of researchers in a kind of semiotic jeopardy between the value of knowledge and the lack thereof. For example, Epstein (2012) details why the pharmaceutical company Merck avoided performing clinical trials on boys when it developed its adolescent HPV vaccine. This avoidance can't be explained through an understanding of virology or the efficacy of the drug's early animal trials – by those measures the vaccine might have been hypothesized as preventing cancer in both girls and boys. Instead, the company avoided male clinical trials because, if successful, the drug would be implicated in the prevention of anal cancer among male teens having anal sex – a far less desirable symbol for the company than the drug's eventual subsequent launch as a "vaccine for cervical cancer." This is a special kind of undone science – one we might characterize as a semiotically induced ignorance, of which we shall consider various formations ahead.

In many of the upcoming examples, we also witness an ignorance of financial inputs. These correspond closely with forms of ignorance about both material and energy inputs. Financial, material, and energy inputs are connected in the sense that monetary currencies ultimately represent a promise of natural material extraction and a financial economy can be seen as a coordinating story to divide up the obligations and benefits of that natural material extraction – all of which depends on flows of energy in the form of fuel, fertilizers, labor, an so on. And as a result, we are therefore dealing with forms of forbidden knowledge, those that can be existentially threatening.

We will also be exploring forms of *in situ* ignorance to the effects of technique in actual use, closely related to the concept of unintended consequences. These in turn often involve historical ignorance or institutional amnesia regarding past measurements, observations, and realizations. We will additionally focus on the role of assumptive ignorance in the development of intermittent energy technologies that are assumed to offset fossil fuels and question whether technological innovation can arise, persist, or even thrive through the service of such assumptions. Sometimes ignorance is professionally acquired or requires technical expertise. Consider Dewey's "occupational psychosis" (see Burke, 1954) or the concept of "trained incapacity" (see Burke, 1954) both related to Mannheim's (1936) "particular conception" of ideology. These generally hold that an individual's preconceptions can create blind spots, allowing past experience to detrimentally affect decision-making as conditions change. Also extending from a psychological dimension, is the work of Becker (1973) who aimed to clarify human actions and motives by shining a light on practiced self-deceit. He argued, "for centuries man lived in the belief that truth was slim and elusive and that once he found it the troubles of mankind would be over. And here we are in the closing decades of the 20th century, choking on truth. There has been so much brilliant writing, so many genial discoveries, so vast an extension and elaboration of these discoveries – yet the mind is silent as the world spins on its age-old demonic career" (p. xviii). Specifically relevant to our energy society, and perhaps of interest to agnotologists, I will propose an extension of the phenomena of non-knowledge to include a class or an age – the epoch of an entire field – that shares an encumbering worldview. Similar to what Mannheim (1936) calls a "total conception" of ideology, this dissertation attends to not just one energy technology, or even the field of energy, but to an entire coproduced genre of belief. This potential conception presses us to think beyond simple considerations of *just* scientific data, or *just* economics, or *just* new energy technologies, or *just* environmental constraints, or just any single part of the broader regimes of energy production and use (Hughes, 1987). Rather, we may consider the *relationships, communications, and shared beliefs* between the various constituents.

These considerations bring us out of the individual mind or group mindset and into what I will term a rhetorical genre of instrumental non-knowledge. To be clear, this research does not aim to take sides on the politics of non-knowledge or pursue the work of discrediting individuals or institutions. This work does not seek to answer questions; rather the aim here is to identify potential *unasked* questions about a hegemonic genre – to throw our predisposed conceptions off balance. Fairclough (2001) identifies that "a particular social structuring of semiotic difference may become hegemonic, become part of the legitimizing common sense which sustains relations of domination" (p. 104). More specific to the textual analysis ahead, McCarthy (1991) argues that a text can shape reality in that it "defines as authoritative certain ways of seeing and deflects attention from other ways. It thus stabilizes a particular reality and sets the terms for future discussions" (p. 359). We will consider how the hegemonic consolidation around just one ecosystem impact measure – nominal carbon dioxide emissions – is possibly arbitrary and may constitute a form of ignorance through aperture and depth of field. By aperture, I am referring to a narrow focus on a single scale that consolidates discourse and capital flows into highly directional streams, which can in turn draw attention away from other scales. And by depth of field, I mean to point out the difference between nominal measurement of a practice, such as refueling an electric car, and the measurement of a practice *in situ*, such as a car that drives on asphalt, which requires bitumen, which requires petroleum exploration, which requires expertise, which requires universities, which requires cafeterias, and so on. We shall see ahead that problems of narrow aperture, low depth of field carbon emissions can rhetorically be solved, it would seem, by similar narrow aperture and shallow market driven solutions amenable to geopolitical capital interests. And in this brief example, we uncover our first opportunity for considering applied ignorance as a strategic asset in technological industrialization and in innovation networks more broadly.

2.2 The role of unintended consequences

Green technologies (e.g. wind turbines, solar cells, and biofuels) and initiatives (e.g. efficiency, recycling, and organics) yield distinct unanticipated consequences that can partially or fully offset intended environmental benefits (Graetz, 2013; Herring 2009; Huesemann, 2011; McGee, 2016; Tverberg, 2012; York 2012; York 2017; 2016; Zehner, 2012; Jensen, Keith, & Wilbert, 2021). Intentional human actions cause multiple effects. Some of these effects are planned while others occur unexpectedly. Unintended consequences are unplanned outcomes that occur due to the implementation of a technology, policy, or other initiative and are typically categorized as beneficial, detrimental, or perverse. I will also be including a fourth category implicit within this analysis, unintended consequences that are controversial. Theorists of economics, political science, history, and sociology have long evoked the concept of unintended consequences, and the notion is imbedded in other common concepts such as SNAFU, Murphy's Law, serendipity, windfall, the butterfly effect, and perverse incentive. The concept of unintended consequences is central to moral philosophies of consequentialism, which hold that people should judge actions based on the outcomes they create. For instance, in 1848 the French economic journalist, Frédéric Bastiat (2001[1848]), wrote: "In the economic sphere an act, a habit, an institution, a law produces not only one effect, but a series of effects. Of these effects, the first alone is immediate; it appears simultaneously with its cause; it is seen. The other effects emerge only subsequently; they are not seen." Bastiat reasoned that analysts should recognize and account for these unseen effects. Merton (1936) advanced a definition of unintended consequences that would go on to inform much contemporary thought on the subject. He pointed out two methodological pitfalls that arise when putting the term to work. First, social scientists must determine how much of an observed consequence can be rightly attributed to a purposive action. To what extent, for instance, can the rise of organized crime be blamed on prohibition of alcohol? The second challenge for social scientists is to determine the intended purpose of an action in the first place. Consequences of actions can be rationalized after the fact, as exemplified by the horseman, who after being thrown from his horse, declared that he was "simply dismounting." Merton argued that interested parties may occasionally be so eager to realize the immediate effects of an act that they give no consideration to other potential consequences. Similarly, people may overlook further consequences when their fundamental values oblige them to pursue an action, leading the resulting unintended consequences to actually inform basic values over time.

Contemporary works typically consider unintended consequences to be negative or positive but they may also be perverse, neutral, or even controversial. The actual categorization may depend of course on the observer's perspective. For instance, a medical drug produces many effects. Some are intended while others are not. The most common classifications of unintended consequences are:

Positive – The drug yields a beneficial side effect in addition to the intended effect. Aspirin is a pain reliever but also acts as an anticoagulant, which can help prevent heart attacks and reduce damage caused by thrombotic strokes.

Negative – The drug produces a detrimental side effect in addition to the intended effect. HIV medications save lives but they can reduce a user's appetite and trigger nightmares.

Perverse – The drug produces exactly the opposite of the intended result *in situ*. Antibiotics can induce antibiotic resistant strains of bacteria. Also, doctors have discovered that some drugs intended to prevent heart arrhythmias actually turned out to be pro-arrhythmic in practice.

Public policies, environmental initiatives, business dealings, and other human undertakings regularly produce unplanned outcomes as well and therefore they are a topic of concern and study across a wide spectrum of disciplines. For instance, developmental economists have claimed that in some cases simplistic food aid can worsen long-term food security of a target region if international organizations deploy the aid without accounting for local economic conditions. If a community is flooded with free food from abroad, local farmers cannot compete and may subsequently earn too little to plant their fields the following season. In this case, the food aid induces the perverse unanticipated consequence of worsening food security by putting local farmers out of business. Developmental economists may develop anticipatory strategies for avoiding such consequences. For instance, a charity might secure funds for local farmers or introduce the food aid at market prices so local farmers can compete with the imported food.

When San Francisco banned disposable plastic bags, stores switched to sturdier paper and reusable plastic bags. However, consumers still disposed of the thicker-walled bags, leading to greater stress on city waste facilities than before the plastic bag ban had been implemented. In contrast, Seattle stores charged a small fee for each bag. Shoppers brought their own reusable bags to avoid the small charge. This policy yielded the intended effect of decreasing waste without the perverse unintended consequence initially experienced in San Francisco (Now both cities operate with a fee policy). However, critics point out that while bag charges are successful from a waste and carbon perspective, bag fees place an unintended disproportionate burden on poor residents.

Numerous mainstream environmental organizations and concerned citizens throughout the world support organic, fair trade, and local food initiatives. These movements aim to bring agriculture, food processing, and distribution activities in line with ecological justice and sustainability principles. These initiatives yield many intended benefits but their successes are at least partly offset by detrimental unintended consequences. For instance, Fairtrade programs aim to assist small farmers by guaranteeing that buyers will purchase their commodities, such as coffee and sugar, at a price above market value. This system has been implicated in producing two distinct negative unanticipated consequences. First, guaranteeing an elevated price leaves producers with no incentive to maintain or improve quality. Second, Fairtrade subsidies may block market signals by subsidizing goods that are being overproduced. Typically, overproduction drives prices lower, signaling producers to switch to other crops. Fairtrade subsidies can prevent this signal from getting through and may even attract more producers to market. Intensified overproduction shoves market prices even lower. This risks leaving all non-Fairtrade producers poorer unless program directors institute measures to counteract this unintended consequence.

In another example, local foods often require little energy to distribute. However, if local farmers employ heated greenhouses or inefficient transport methods, locavores may unintentionally expand their energy footprints when prioritizing local fruits and vegetables over those shipped from warmer climates via efficiently-packed containers. While 'locavorism' may benefit local farmers and communities, it can unintentionally hurt export farmers in the global South.

As a final example, organic farmers reduce environmental harms stemming from pesticides and fertilizers. However, organic farming techniques require extensive plowing in order to control weeds. This in turn requires more petroleum and for this and other reasons organic farming has been associated with an increase in overall fossil fuel use and greenhouse gas emissions (McGee, 2015). Additionally, to the extent that organic farming is more land intensive than conventional farming, organic foods unintentionally places rainforests and other sensitive areas at risk. Here, the intended benefits (reducing fertilizer and pesticide contamination) are difficult to weigh against the unintended consequences (increased petroleum use and rainforest endangerment).

These examples display modes of attending to unanticipated outcomes, involving negotiation and renegotiation in an anticipatory consequentialism, which is both temporally and materially compelled. Green energy technologies generate unanticipated consequences of their own and they are not, as a part of an established renewable energy regime, immediately amenable to the renegotiation of anticipatory consequentialism exemplified above. In the case of green technologies, consequentialist anticipation may threaten an existential crisis. Support for these technologies relies on their semiotic classification qua "green" so from the start it would presumably be valuable to ensure any consequentialist negotiations be selectively framed in a way to either avoid existential reckonings or strengthen the green semiotic classification. Otherwise, these regimes risk crisis, in which the very value-added feature, "green" or "clean," comes under scrutiny. Through consequential framing, the question can become not "how green are solar cells?" but instead, "how are solar cells green." And in the more sophisticated mode of consequential framing, the question can evolve from, "to what extent is the solar technology regime destructive?," to instead "how do we make solar technologies greener?" These iterative modes of interrogation do not erode the green veneer of renewable energy technologies, but rather calcify it, making the regime resilient to the sort of environmental attacks that might deteriorate the credentials of other industrial processes.

This phenomenon might be sidestepped altogether through forms of material semiotic classification, which subvert the iterative and often reflexive process of renegotiation in part through the power of what we might call consequential agnosticism. As with traditional energy production, the consequences arising from green technologies can generate political tensions. Once a government or organization backs a certain green technology, it risks losing credibility if detrimental consequences are exposed. Consider the following examples.

To begin, in 2008 riots broke out around the world in response to rising corn prices. Some blamed the increase on weather conditions, others claimed that demand from India and China was to blame. The World Bank studied the price jump but kept its findings secret, presumably because they might have upset the bank's major donor, the United States. However, The Guardian obtained a leaked copy of the report and published its findings. The World Bank study group had determined that the rise in corn prices was an unintended consequence of green biofuel production and concluded that green energy producers' demand for corn pushed prices higher for everyone, including those who needed corn for food (Chakrabortty, 2008).

Biofuel producers can refine fuel from sugarcane instead of corn but critics maintained that sugarcane cropping practices endangered rainforests and biodiversity. Authors of an article at the time, published in the journal Science, argued that the benefits of producing biofuels from sugarcane were greatly diminished if the unanticipated consequences of sugarcane production were taken into account arguing that carbon rich rainforests were frequently leveled to make room for sugarcane plantations (Scharlemann, 2008). This, they claimed, not only interrupted the carbon cycle but also endangered local biodiversity, hydrological functioning, and soil stability. Additionally, crop residues left behind from farming activities released methane, a greenhouse gas with 23 times the warming potential of CO_2. Furthermore, fertilizing fields of sugar, corn, rapeseed, and other biofuel feedstocks with nitrogen rich fertilizers yielded nitrous oxide. Nitrous oxide has a global warming potential 296 times greater than CO_2 and additionally damages stratospheric ozone. Debates on the net CO_2 emissions of ethanol did not stop the subsidies, and subsequently the industry, from expanding.

A broader consequential ignorance became a plausible strategic political asset for exporters and agribusinesses, whose products and technologies were at risk. And, through a narrowing of focus to greenhouse gas emissions as the principle measure of impact both proponents and critics may stand to benefit from ignorance to the vast array of ecosystem impacts such as habitat loss to the degree they value growth through "alternate" means (Gibbs, 2020).

When individual or organizational energy consumers institute energy efficiency measures, such as using more efficient light bulbs or machinery, they also save money on energy. However, these entities may choose to spend these savings on other products or endeavors that still lead to energy consumption. In this case, money-saving energy efficiency measures can unintentionally stimulate other forms of consumption, leaving overall energy footprints unchanged. The foundational theory of such an unintended consequence of energy efficiency is termed the Jevons paradox. It is named after William Stanley Jevons who in 1865 explained how James Watt's introduction of the steam engine greatly improved efficiency, which in turn made steam engines more popular and subsequently drove the use of coal ever higher. Could alternative energy tech instigate corresponding unintended macroeconomic consequences that remain unrecognized as well? Alternative energy promoters aim to reduce dirty fossil fuel use by expanding clean energy production. However, increasing any form of energy supply, most particularly those that are subsidized, may exert downward pressure on retail energy prices, thereby possibly stimulating overall demand for energy services - a boomerang effect. Without appropriate countermeasures, any increase in energy production, alternative or conventional, may unintentionally perpetuate energy intensive modes of living. Furthermore, when energy consumers believe their energy is derived from clean sources, they may be less concerned about conserving it (York, 2017).

Since unanticipated consequences follow directly or indirectly from human activities but occur at a future time and possibly in a different location, they can be difficult to identify or directly link to a triggering activity, instigating what Murphy (2006) identifies as regimes of perceptibility, wherein knowledge production arises from diminished awareness of certain phenomena in the service of making others more prominent. Of relevance to this work might be regimes of consequential imperceptibility, strategically or otherwise acculturated into green energy narratives, perhaps contributory or even necessary for the specific formation of correlated technological innovation.

2.3 Ignorance in academic climate activism

The Solutions Project, a group aiming to “accelerate the transition to 100% clean, renewable energy for all people,” was originally led by a ten person board including Mark Jacobson, a prominent Stanford engineer; Marco Krapels, a banker; Van Jones, a political strategist; Mark Ruffalo, an actor; Josh Fox, a filmmaker; two associates of the actor and philanthropist Leonardo DiCaprio; an attorney, and two solar industry executives. As might be expected, the group claims to “engage the public, celebrate and convene leaders, and advance partnerships and policies,” but what is perhaps more telling is the group’s main tool, reported on their federal disclosure forms simply as: “Storytelling.” It is the seduction of story that brings this diverse set of actors, politicians, scientists, bankers, and industrial leaders together for a common goal. And, in an increasingly secular world, perhaps our thirst for their story grows stronger as we look to fulfill our desire for existential reassurance that, as energy technology proponent Mark Jacobson stated on the Late Night Show with David Letterman, “everything will be ok.”

Such storytelling is not limited to late-night television shows and when one takes interest in looking for it, can be found in great quantities throughout public policy and the peer-reviewed literature. In fact, we must consider that the peer-review process may be a relatively good conduit for semiotically induced institutional ignorance, a topic that could be of interest to other researchers but is beyond the scope of this work. Here we will briefly consider as an example the potential for varied forms of necessary ignorance immanent in the works of Jacobson et al (2009; 2011; 2013; 2014; 2015; 2016a; 2016b) needed in order to mobilize innovation toward a future running principally on wind, water, and solar energy. Jacobson et al (2009; 2011; 2013; 2014; 2015; 2016a; 2016b) make the argument that there is ample availability of hydro, wind, and solar energy to power the entire planet with renewable energy. This is supported through measurements of the aggregate amount of sunlight and wind, which are then compared to global power consumption. Due to space constraints for this dissertation, we will view how this corpus appears to mobilizes just three useful and potentially necessary forms of ignorance in particular, including 1) ignorance through selective misattribution of limits, 2) assumptive ignorance to the ability of solar and wind energy to replace fossil fuel use, and 3) a structural linguistic ignorance enabled through the flexibility of the term "renewable energy."

To begin, throughout this corpus (Jacobson, 2009; 2011; 2013; 2014; 2015; 2016a; 2016b) we see stated in various terms that that the availability of sunlight and wind does not limit solar and wind technologies from powering most of the planet. To a naive observer this might be seen as akin to stating that the availability of rocks on the planet does not limit our ability to construct everyone a castle. Yet, the limit to building everyone a castle is not the availability of rocks but rather financial costs, which can be broken down into labor and ultimately energy costs for food, shelter, transportation, extraction, and so forth. One might similarly conjecture that the limits to solar and wind systems are minimally subject to aggregate sunlight and wind limits and primarily subject to fossil fuel and temporal limits. These in turn also manifest as financial limits. We might then investigate whether the high cost of solar and wind energy technologies reflects a variety of intermediary costs such as labor, materials, fabrication, transportation, installation, and maintenance. Under current global economic arrangements, financing itself is additionally is closely linked to natural material extraction, which in turn is nearly entirely reliant on fossil fuels. Are there any costs of solar cells and wind turbines that are not ultimately reducible to fossil fuels? Such considerations could introduce a fossil fuel constraint to deploying solar cells and wind turbines that is presumably significantly below the limits posed by aggregate access to sunlight and wind (Economist, 2021). Might this narrowing of aperture, achieved through creating a performance of measuring the limits of sunlight and wind, be necessary in order to create an impression of abundance and subsequently open a space for the role of innovation to exploit the perceived abundant resource? It is in this manner that we may begin to envision ignorance as a primary resource upon which the wind and solar technology innovators could perhaps draw upon to signify a market opportunity for investors, researchers, and other innovation partners.

Regarding the role here of assumptive ignorance, the Jacobson et al (2009; 2011; 2013; 2014; 2015; 2016a; 2016b) corpus routinely compares energy potentials of varying qualities as if they are equivalent and interchangeable. And indeed this assumption is evident in most published literature on the subject including cornerstone reports published by the IPCC (2007; 2011; 2014) and OECD (IEA 2012; 2013; 2016; 2019; 2020). For instance, these works compare hydropower, which is a dispatchable supply, along with wind power and solar power, which are not dispatchable (see for instance Jacobson, 2013 Tables 1, 2, 3, & 4).

Figure 2.1: Jacobson et al equally compare energy supplies of dramatically varying qualities, implying they can offset or replace one another, which might be understood as a form of assumptive ignorance pervasive in much climate and energy work including that of the IPCC and OECD. In this case, the chart shows WWS (wind, wave, solar) replacing dispatchable conventional fuels.

Energy sector	Conventional fossil fuels and wood 2010			Conventional fossil fuels and wood 2030			Replacing fossil fuels and wood with WWS 2030		
	World	U.S.	NYS	World	U.S.	NYS	World	U.S.	NYS
Residential	1.77	0.38	0.026	2.26	0.43	0.025	1.83	0.35	0.020
Commercial	0.94	0.28	0.023	1.32	0.38	0.025	1.22	0.35	0.022
Industrial	6.40	0.86	0.009	8.80	0.92	0.009	7.05	0.74	0.007
Transportation	3.36	0.97	0.036	4.53	1.10	0.037	1.37	0.33	0.011
Total	12.47	2.50	0.094	16.92	2.83	0.096	11.47	1.78	0.060
Percent change							(−32%)	(−37%)	(−37%)

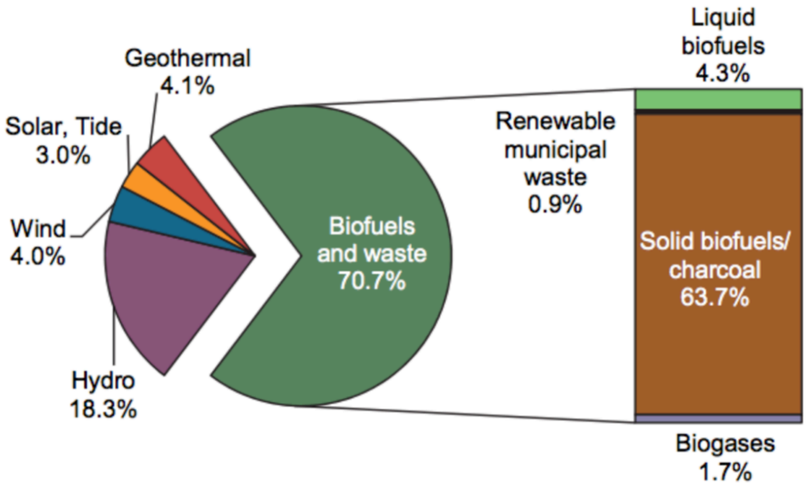
Solar and wind power systems incur costs for power conditioning, battery backup, or concurrent conventional infrastructure to fill gaps in service due to intermittency. For instance, the world's largest solar array in Ivanpah, CA has three natural-gas-fired power plants hidden within the compound, as well as diesel generators.

Figure 2.2: A photo of the natural gas pipeline interconnect inside the Ivanpah solar facility.

The San Gorgonio Pass Wind Farm outside Palm Springs, CA also has a large natural gas plant built in the center of the array of turbines to provide power conditioning to the intermittent wind supply. These intermediary power conditioning costs in turn indicate primary energy costs, which are principally supplied through conventional fuels. Until power-conditioned solar and wind costs fall below the costs of fossil fuels they rely upon, might these technologies in effect represent fossil fuel consumption by alternate means? And, even if lower technology costs are achieved, then might they stimulate growth in the broader economy? In this case, might they also stimulate demand from economic sectors that are reliant on fossil fuels (Garrett, 2011)? To make an equivalent comparison, measurements of intermittent power supply would presumably need to be adjusted to account for the energy imprint of creating storage, the impacts of deploying a concurrent fossil fuel supply, or some other mode of power conditioning. Additionally, available empirical data suggest that solar and wind power have not offset fossil fuel use in practice (York, 2012; 2016; Gibbs, 2020). Nevertheless, might the performance of an equal comparison between power production strategies of varying qualities be necessary in order to craft the assumption that solar and wind technologies will offset fossil fuel use and therefore mitigate greenhouse gas emissions? Can the impression of an offset be maintained without such assumptive ignorance? Might we also characterize this as a type of necessary existential ignorance? That is, if wind and solar technologies do not ultimately offset fossil fuel use, then would the entire renewable energy project encounter an existential threat?

A final potential role for ignorance that we will consider for this example is a structural linguistic ignorance, semiotically induced, potentially inherent in the term "renewable energy." As has been anecdotally exemplified by Gibbs (2020), activists who may consider themselves to be renewable energy advocates may be shocked to discover that what is counted as "renewable energy" globally is roughly 70% bioenergy – the burning of living forests, plants, and animals for energy. Across the world, nature is being incinerated to meet climate targets ostensibly concocted to protect nature (Gibbs, 2020; Neslen, 2016). Figure 2.3 is a chart from the IEA, which presents a rare side-by-side accounting of the constituents of what is considered to be renewable energy globally. The organization no longer publishes this side-by-side comparison and instead tabulates the figures in separate charts using differing units of scale. Another large chunk of the renewable energy pie is hydropower, the limits and disadvantages of which, including habitat destruction, methane emissions, and wildlife obstructions, are widely accounted for among renewable energy advocates. Meanwhile, nominal reported solar and wind power production amount to very little in comparison. Despite their symbolic prominence in the clean energy movement, wind turbines and solar cells are not major components of what is globally counted as renewable energy, so why do environmental groups feature them as such?

Figure 2.3: When people think of renewable energy, they typically envision windmills and solar cells but seventy percent of what is considered renewable energy globally is bioenergy, involving chainsaw and smokestacks. Less than 10% of renewable energy is wind and solar. This chart from the IEA presents a rare side-by-side accounting of the constituents of what is considered to be renewable energy globally. The organization no longer publishes this side-by-side comparison and instead tabulates the figures in separate charts using different units of scale. Source: International Energy Agency, OECD, 2017 World Energy Outlook, (© International Energy Agency, OECD, used with permission[3])



Many works, including scholarly papers, activist websites, and media coverage, draw upon the structural linguistic ignorance renewable energy's primary component in the service of valorizing the development of wind and solar technologies instead. They presumably find it semiotically valuable to display wind turbines and solar cells on their websites rather than the chainsaws and smoke stacks that represent the vast majority of what constitutes renewable energy.

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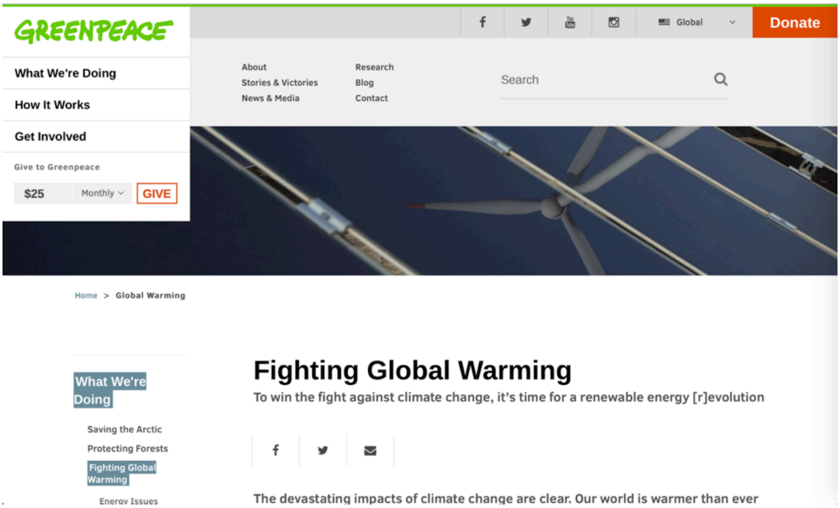
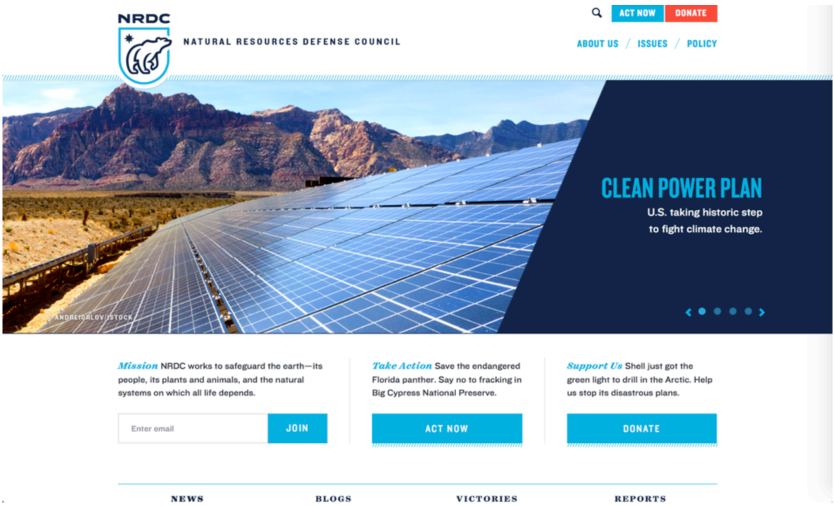
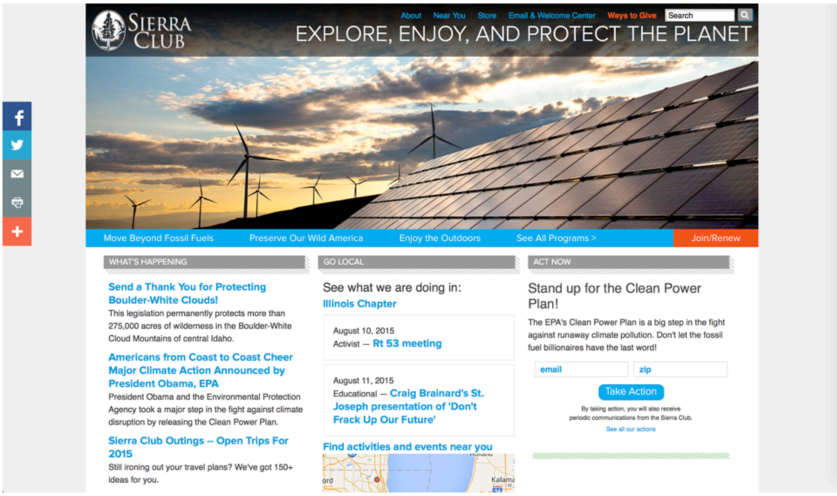
[3] © OECD/IEA 2017 World Energy Outlook, IEA Publishing,. Licence: www.iea.org/t&c The associated research does not necessarily reflect the views of the International Energy Agency.

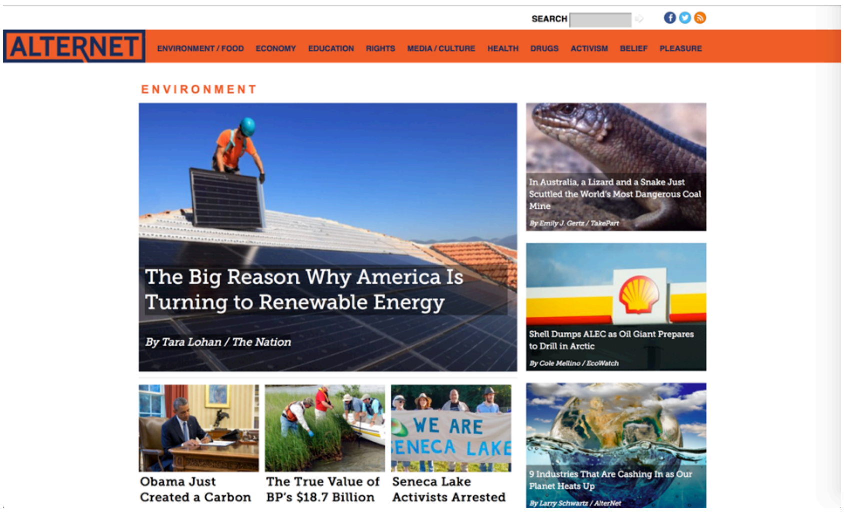
Figure 2.4: Environmental groups, including Greenpeace, NRDC, Sierra Club, as well as environmental media, including Alternet, employ the symbolism solar and wind technologies to support legislation that ultimately and primarily supports the burning of trees, plants, and animals. (Sources: Greenpeace, NRDC, Sierra Club, Alternet, 2015)





(*Figure 2.4 continued*)





In our case at hand, Jacobson et al (2015) present a chart, published through a peer-review process at the Royal Society of Chemistry, that shows "renewables" in 2015 representing 5% of U.S. power supply as a mixture of wind, solar, hydro, and geothermal power (Figure 2.5). However, this contradicts the mix of renewable energy reported by U.S. government data, indicating that renewable energy in the U.S. is principally derived from burning trees, plants and animals - not wind and solar power (Figure 2.6).

Figure 2.5: In a rather common fashion, Jacobson et al (2015) display a chart indicating that renewables consist principally of wind, solar, hydro, and geothermal power in 2015 and into the future.

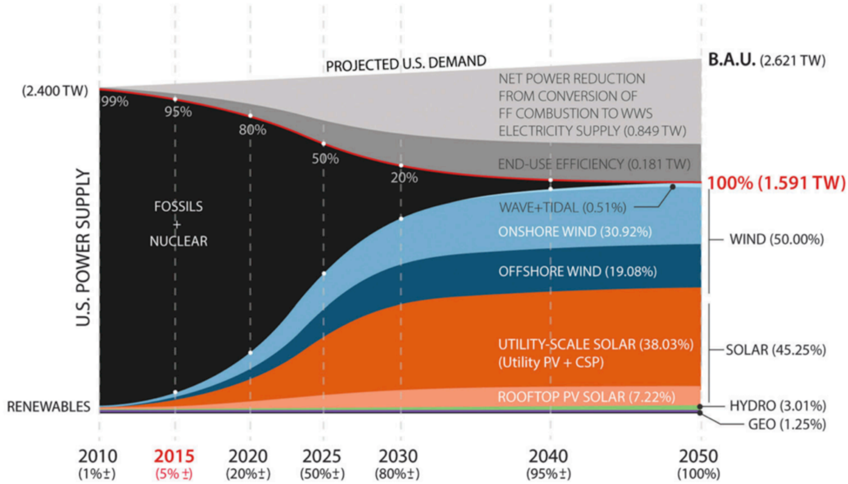
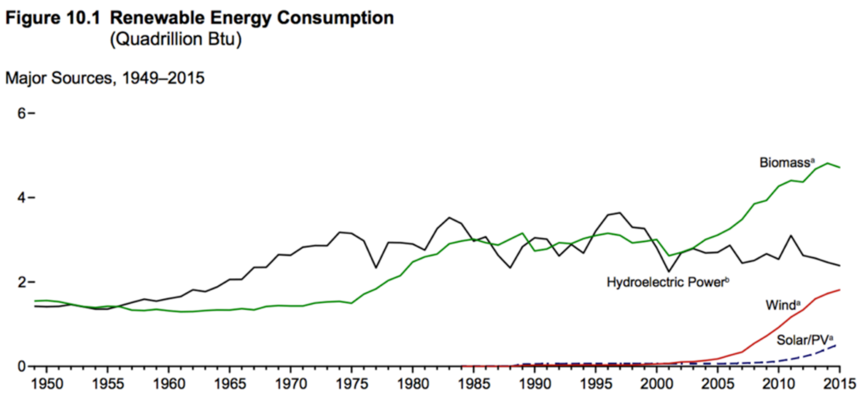


Figure 2.6: What counts as "renewables" is not principally a mixture of wind and solar as the above chart, peer reviewed and published by the Royal Society of Chemistry indicates; according to U.S. government data, the largest share of what counts as renewable energy in the United States is biomass, burning of the living world for fuel, which has always represented a much larger share of energy consumption than solar and wind power consumption combined. Source: US Department of Energy, 2016



Does this illusory aspect of the term "renewable energy," in which there is a disconnect between the referent and the referred, create a valuable disconnect between perception and reality? (see also Hornborg, Cederlöf, & Roos, 2019) Specifically, are tree-hugging activists advocating for renewable energy policies to principally cut and burn trees? The mechanisms by which this potential illusion operates and spreads through media, itself presented here as a material semiotic relationship, will arise as a central thread of this dissertation moving forward.

2.4 Ignorance in supporting cost decline in solar technologies

Let's next consider the belief that solar cells costs are falling. This is an almost universal signifying characteristic of green technology proponents and is published in academic journals as frequently as it is presented in global press. Full articles have appeared on the phenomenon in The New Yorker, The Guardian, and many other mainstream publications.

Figure 2.7: Numerous news and scholarly publications cite dramatic reductions in the cost of solar and wind technologies (Sources: The Guardian and Bloomberg)


theguardian

pinion sports soccer tech arts lifestyle fashion business travel environment ≡ browse all sections

gy pollution climate change wildlife

'Spectacular' drop in renewable energy costs leads to record global boost

Falling solar and wind prices have led to new power deals across the world despite investment in renewables falling

Solar panels on sale at the Naran Tuul market in Ulaanbaatar, Mongolia. Photograph: Seong Joon Cho/Getty Images

Most popular in US

Las Vegas shooting: death toll rises to 50 as police name suspect - latest updates

Mandalay Bay attack: at least 50 killed in deadliest US shooting

What we know about the Las Vegas shooting

Witness footage of Las Vegas music festival shooting - video report

(Figure 2.7 continued)


Bloomberg

Solar Could Beat Coal to Become the Cheapest Power on Earth

Solar Could Beat Coal to Become the Cheapest Power on Earth

By Jess Shankleman and Chris Martin

January 2, 2017, 5:00 PM MST Updated on January 3, 2017, 5:16 AM MST

- Global average solar cost may fall below coal within 10 years
- Countries from Saudi Arabia to Mexico planning auctions

SOLAR MAY BEAT COAL IN A DECADE

SOLAR WIND CCGT COAL

350 300 250 200 150 100 50

DOLLARS PER MEGAWATT-HO

THE LINCOLN MOTOR COMPANY
LINCOLN MKZ
HYBRID
LEARN MORE

On the face, these accounts seem convincing; the nominal price of solar cells has been reported as dropping over recent years and the solar industry is frequently symbolically compared to the microelectronics industry and Moore's Law (see Chapters 3 and 4). However, we will consider here whether one of many aspects of this perceived rapid drop in retail costs involves ignoring the corresponding and significant rise in government subsidies for every stage of solar cell research, development, fabrication, and implementation. The phenomenon of a subsidy differs from the phenomenon of a drop in cost. For instance, when the Saudi royal family issues a subsidy for gasoline, editors at The New Yorker and The Guardian don't characterize it as a price drop in the fuel. But when it comes to solar subsidies they do, exemplified by a New York Times article that refers to solar subsidies but leads with the headline, "Solar and Wind Energy Start to Win on Price vs. Conventional Fuels" (Cardwell, 2014). Do such moments represent forms of material ignorance, which allow for instrumental beliefs that can organize political and financial resources around innovative activities? If solar photovoltaic power is less expensive in practice than fossil fuel power, as some proponents claim, then why don't energy firms abandon the more expensive fossil fuels? Are they making bad business choices, or is there more to the story? And, if solar and wind power are less expensive than fossil fuels in practice, then why would hundreds of billions of dollars be needed to subsidize their usage?

Figure 2.8: This New York Times lead makes the common assertion that wind and solar electricity is cheaper than natural gas and coal. If solar photovoltaic power is less expensive in practice than fossil fuel power, then why don't energy firms abandon the more expensive fossil fuels? And, if solar and wind power are less expensive than fossil fuels in practice, then why would hundreds of billions of dollars be needed to subsidize their usage? Also note the non sequitur about oil, as wind and solar electricity are minimally fungible with oil. Source: New York Times, 2020

The New York Times

Oil Companies Are Collapsing Due to Coronavirus, but Wind and Solar Energy Keep Growing

In many parts of the world, including California and Texas, wind turbines and solar panels now produce electricity more cheaply than natural gas and coal.

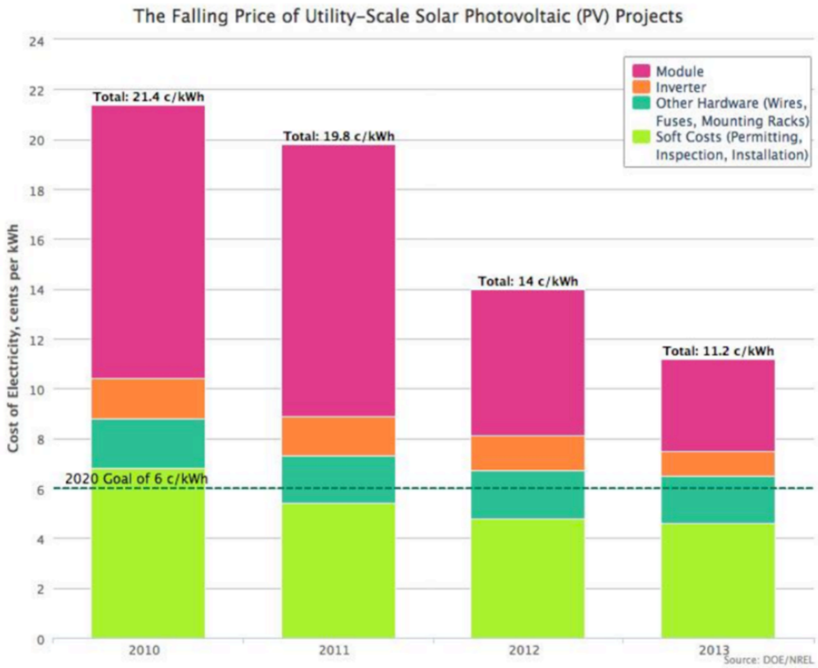
Apr 27, 2020

What is at stake here is more than just political or economic impressions of cost. What does the cost of a solar cell or other industrial energy technology represent if not its energy inputs for materials, labor, and other factors such as situ effects on the electrical grid? Smil (2017) states that "to talk about energy and the economy is a tautology" (p. 344). He explains, "every economic activity is fundamentally nothing but a conversion of one kind of energy to another, and monies are just a convenient (and often rather unrepresentative) proxy for valuing the energy flows" (p. 344). Admittedly, the value of fine art may not reflect the energy inputs that went into making it. However, the monetary value of a material or industrial commodity is a different case. How does the monetary cost of an industrial commodity correspond to the quantity of energy inputs used to pull it from the earth and process it into a usable form? The relationship between energy and monetary value is variable, important, difficult to trace, and almost entirely ignored in the literature. That said, we may surmise that the cost of an industrial good *says something* about its energy inputs. And, if the cost of an energy technique is more expensive than the fossil fuels used to create it, then that higher cost must be explained. Where did the higher cost arise if not from fossil fuel inputs? “Labor” might seem an immediate answer, and in fact nearly all of the literature on energy accounting for renewable energy sidelines labor as a separate cost exempt from energy accounting (see Roos, 2021). However, labor relies on at minimum transportation, shelter, and food – all of which themselves rely on significant but difficult to calculate fossil fuel inputs. Tabulation complexity makes the long tail of energy inputs easy to discount as a note or even completely ignore. This much we have seen, but there is more to ask. Does the innate complexity in tracing energy inputs of technologies open a space to eventually draw upon this non-knowledge as a resource for justifying innovative activity?

In May of 2014, the Obama White House released a statement that “the average price for a utility-scale PV project in the United States has dropped from about $0.21 per kilowatt hour in 2010 to $0.11 per kilowatt hour at the end of 2013” – a triumphant achievement that the Obama administration linked to “unlocking American jobs and innovation” (White House, 2014, pp. 2-3).

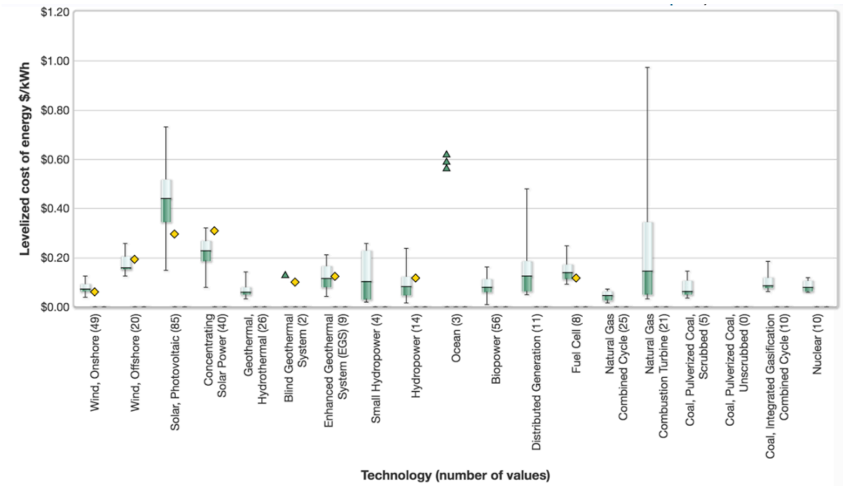
Does this case present a potential value in employing a willing material ignorance regarding the impact of subsidies on the reported retail price drop? To put this in perspective, that year, in 2013, the solar industry received at least $56.9 billion in direct subsidies and generated 106,364 GWh of energy according to the International Energy Agency (IEA, 2014). This figure does not include additional support to solar in the form of defaults and losses from pension funds, private equity, and other sources of direct and indirect support. To understand the rough scale of that subsidy in relation to the output that year, the direct subsidy equated to $0.14 per kilowatt hour if amortized over the assumed 25 year lifespan. In other words, the amount per kilowatt-hour spent on solar subsidies alone was larger than the purported retail cost of solar energy being claimed by the administration.

Figure 2.9: The White House issued this chart showing that solar cell costs had dropped to 11.2 cents per kilowatt-hour in 2013 but during that year, more than that had been spent on just solar subsidies alone. Source: U.S. White House press release, 2013



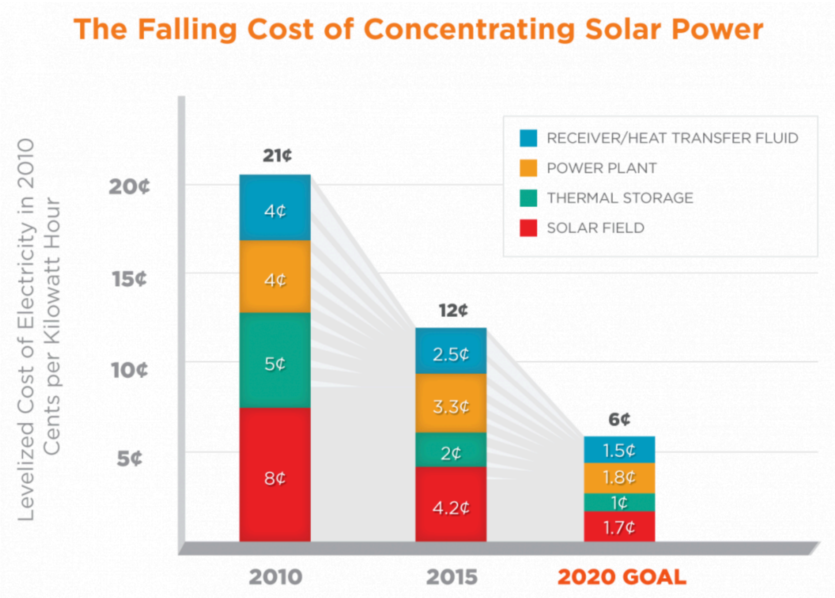
But in this case it gets even more interesting. The Obama administration's Department of Energy and the National Renewable Energy Laboratory collect data on the costs of numerous energy technologies, which attempt to account for capacity factor and other attributes of solar photovoltaic panels *in situ* - termed the "levelized cost" (Energy Information Administration, 2016). The 11-cents per kilowatt hour estimate developed for the White House by the National Renewable Energy Laboratory was reported to be a levelized cost "based on certain assumptions," which are not detailed in the White House release. However, according to the *Transparent Cost Database* sponsored by the National Renewable Energy Laboratory and containing data from the Department of Energy, the levelized cost of solar photovoltaic energy at the time ranged from about $0.15 to $0.75 per kilowatt hour with an average of just over $0.40 per kilowatt hour – four times the cost reported by the White House. Was the White House release made intelligible and actionable only given *in situ* ignorance of existing data on the industry, as well as data from its own energy department? We will return to this question in chapter 7.

Figure 2.10: The Department of Energy claimed that solar costs in the field were on average four times higher than the White House press release indicated. Source: U.S. Department of Energy



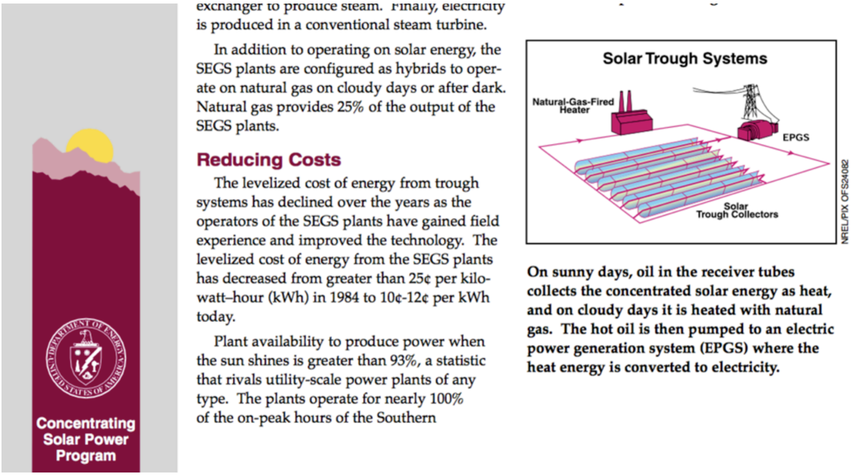
In another example, the Department of Energy's SunShot Initiative, established in 2010 and designed to "support research and development" of centralized concentrating solar thermal (not photovoltaic) power (CSP), released this statement about the initiative's performance through 2016: "Since SunShot's inception, the levelized cost of electricity for CSP has decreased about 36 percent, from $0.21 cents per kilowatt hour to $0.13 (sic) cents per kilowatt hour, already over half of the way toward achieving the SunShot goal."

Figure 2.11: The Department of Energy SunShot Initiative claimed in this 2016 release that solar thermal costs had dropped from 21-cents to 12-cents (est.) per kilowatt-hour. Source: U.S. Department of Energy



The intriguing observation here is that the Department of Energy had been repeatedly publishing the same "dramatic-cost-drop" claim over the past three decades, every time as if it were a legitimately original milestone. A 1998 report by the Department of Energy contains an almost identical statement about concentrating solar power. The 1998 report claimed that the levelized cost of energy from concentrating solar plants had "decreased from greater than 25¢ per kilo-watt hour (kWh) in 1984 to 10¢ to 12¢ per kWh today [1998]."

Figure 2.12: The Department of Energy made an almost identical claim about the levelized cost of solar thermal energy in this 1998 report (a drop from 25-cents in 1984 to 10-12-cents in 1998) as it made in the 2016 report above (21-cents in 2010 to 12-cents in 2015). Source: U.S. Department of Energy, 1998



exchanger to produce steam. Finally, electricity is produced in a conventional steam turbine.

In addition to operating on solar energy, the SEGS plants are configured as hybrids to operate on natural gas on cloudy days or after dark. Natural gas provides 25% of the output of the SEGS plants.

Reducing Costs

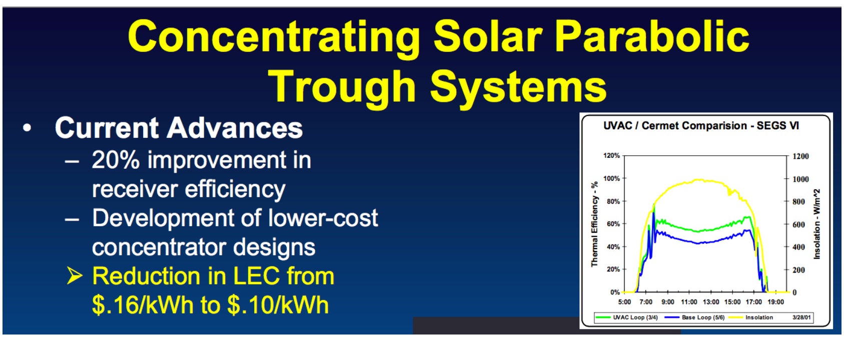
The levelized cost of energy from trough systems has declined over the years as the operators of the SEGS plants have gained field experience and improved the technology. The levelized cost of energy from the SEGS plants has decreased from greater than 25¢ per kilowatt–hour (kWh) in 1984 to 10¢-12¢ per kWh today.

Plant availability to produce power when the sun shines is greater than 93%, a statistic that rivals utility-scale power plants of any type. The plants operate for nearly 100% of the on-peak hours of the Southern

On sunny days, oil in the receiver tubes collects the concentrated solar energy as heat, and on cloudy days it is heated with natural gas. The hot oil is then pumped to an electric power generation system (EPGS) where the heat energy is converted to electricity.

And again, eight years later in 2004, the Department of Energy claimed the levelized cost of concentrating solar had dropped from 16¢ to 10¢.

Figure 2.13: The Department of Energy made an almost identical claim about the drop of the levelized cost of solar thermal energy in this 2004 technical presentation as it made in 1998 and in 2016, identifying an apparent institutional amnesia to the figures that may have been necessary in order to repeatedly mobilize support for solar thermal innovation projects. Source: U.S. Department of Energy, 2004



Nine years went by before the Department of Energy published the purported drop again in 2013, and finally again in 2016. These statements are made possible by narrowing the dataset to only a few years at a time, thus maintaining a historical ignorance, without which the dataset would be unintelligible as a coordinating instrument for mobilizing support.

Such institutional amnesia opens a space for erasure, which may play an important role in the public perception of solar energy technologies and ultimately in the support for billions of dollars in cash flows and federally backed loans to the companies that construct and finance the associated infrastructure, which in this case include Bechtel, The Carlyle Group, Koch Industries, and Google. Relatedly, the National Renewable Energy Laboratory itself is operated by a nonprofit organization named Battelle, which has a sole limited partnership with a for-profit company called Battelle Ventures, which claims to invest in clean tech, including the sectors that its nonprofit wing evaluates on behalf of the Department of Energy. In these examples, we can begin to see how the absence of knowledge – real, perceived, crafted, - could potentially become a strategic *resource* for scientific inquiry and technological industrialization. It is entirely possible that the professionals drafting these data sets were unaware of this historical repetition, as unlikely as that may seem. It is also plausible to suspect these narrowed datasets may represent some form of intentional deception. Or, we might imagine these experts succumbed to some unwitting combination of these factors. In any case, as we shall pick up again in Chapter 5, we often witness an alignment of interests around narratives that synchronize to advance certain, often profitable, green technological ideals.

Chapter 3: Media coverage of energy production versus reduction[4]

There is no divine stance to view our energy metaphors from above; no God-trick, in Haraway's (1988) famous words. But since media both reflect as well as shape public understanding of energy techniques, we can examine media "performances" of energy expectations as co-constitutive of the public understanding and support for energy technologies (see Beder, 2004; Yanow, 1996). Take for instance an example from the history of nuclear power development. On March 16, 1979, Hollywood released a run-of-the-mill film that might have been rather unremarkable had the fictional plot not played out in real life while the movie was still in theaters. *The China Syndrome*, a film starring Jane Fonda, Jack Lemmon, and Michael Douglas, featured a reporter who witnessed a nuclear power plant incident that power company executives subsequently attempted to cover up. In the film, many days pass before the full extent of the meltdown surfaces. Just 12 days after *The China Syndrome* premiered, real operators at the Unit 2 nuclear reactor at Three Mile Island, outside Harrisburg, Pennsylvania, received abnormally high temperature readings from the containment building's sensors. They ignored them.

Many hours passed before these operators realized that the facility they were standing in had entered into partial core meltdown. Power company executives attempted to trivialize the incident and many days passed before the full extent of the meltdown surfaced.

The China Syndrome went viral – what was fiction was now also non-fiction. When star Michael Douglas appeared on NBC's The Tonight Show, host Johnny Carson quipped, "Boy, you sure have one hell of a publicity agent!" The staged nuclear leak filmed in the back lots of Hollywood and the real nuclear leak on Three Mile Island became conjoined, feeding into one another, each event becoming more vividly salient in the eyes of the public than if they had occurred independently. The intense media and political fallout from the leak at Three Mile Island, perhaps far beyond the technical challenges that the leak itself presented,

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[4] Portions of this chapter published in "Conjuring clean energy" (Zehner, 2008) and "Green illusions" (Zehner, 2012).

marked the abrupt finale of the short history of nuclear power development in the United States.

Moving ahead, I will take the perspectives introduced previously as working guidelines. This chapter analyzes how media framed certain aspects of the discourse surrounding energy solutions during the 2003-2008 global energy shock. What assumptions did journalists use to frame potential solutions to this crisis? Why did media focus more on energy *production* than on energy *reduction*? We can view only blurry snapshots but they have the advantage of capturing this energy ethos, which is an inseparable blend of factors including expectations, symbolic meanings, behavior, scientific authority, and psychological states. Moving forward, we will consider the context of energy and economic contraction as a lens to expose some unasked questions about these energy technologies, which apply not just to the public understanding of environmental science but also to the fields of research and policymaking more broadly.

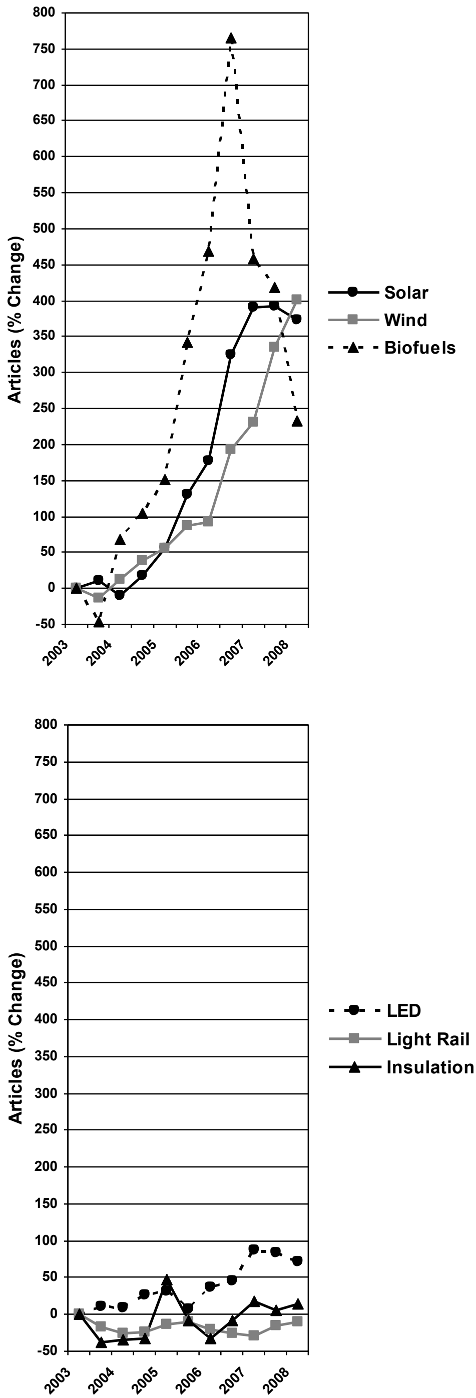
Of the many approaches to studying science communication, Perrault (2013) identifies three specific benefits to analyzing print media. First, textual analysis offers an understanding of the texts of record. It is within this published sphere that arguments form, develop, and become objects of critique among a group of influential peers. Second, a textual analysis of published media allows both readers and researchers access to the source material. Third, print media offers a repository of perspectives and positions, storing matters of identification such as dates and events as well as cultural elements such as metaphors, frames, and symbolic imprints. As mentioned earlier, this dissertation provisionally considers material evidence but it is not intended to form a scientific argument of what the facts *are*, how the world *is,* or what the future *will be*. Nor is the product of this chapter, and ultimately this dissertation, a list of specific policy recommendations, per se. Rather, by contrasting the way popularized media frames energy options in a time of energy distress against some material observations of the presumed solutions, this research is intended to create a platform to better question a potential discordance, with the hope that scholars, governments, and organizations might consider these different types of questions about energy during a time of contraction to perhaps make our analyses more useful, or at least more intriguing.

3.1 Snapshots of productivist media during an energy crisis

From 2003 to 2008 when petroleum prices tripled, media coverage of energy rose to stratospheric highs. LexisNexis, the media database studied for this research, accrued a corpus of roughly 50,000 articles on energy written in US media over those years. For every doubling of oil prices, media coverage of solar, wind, and biofuels shot up 300%. By contrast, media coverage of strategies associated with energy reduction – LED lighting, public transit, and building insulation – remained comparatively low over the same period, averaging just a 25 percent increase (see Figure 3.1).

Further, one in seven articles associated solar cells, wind turbines, and biofuels with "energy independence." We might expect journalists to similarly associate energy reduction strategies with energy independence; a BTU saved is a BTU that doesn't have to be imported. Yet, only a handful of articles – just one in five thousand – made this association.

Figure 3.1: Media featured energy production strategies during energy shock over perceived energy reduction strategies



To explore these differences I had to trim the corpus to a workable size and did so by focusing on the New York Times and the three most widely circulated popular science magazines in the United States at the time: Popular Science, Discover and WIRED (ABC 2006). Together, these mainstream news sources published 62 articles and excerpts of larger articles during the initial three years of the energy shock that covered solar cells, understood as an energy *production* technology, and light-emitting diode (LED) lighting, understood as an energy *reduction* technology. This is a reasonable pairing since both are high-tech devices that were commercialized in the 1960s, exposed to oil shocks, and promoted for military, space, and consumer applications. They co-exist but their developers compete for limited funding and media attention. Whether these two technologies actually achieve their presumed purposes in the real world is a far more complex assessment due to considerations such as rebound effects (Herring, Sorrel, & Elliot, 2009). We have considered some limits and will explore some intriguing ones later. But to begin, we need only to keep in mind that people associate LEDs with energy *reduction* and solar cells with energy *production*.

Through multiple close readings, I discovered three distinct differences between the way journalists wrote about these technologies. In addition to a description of my findings, I built semantic maps to roughly display these three prominent themes using concordance, statistical, and visualization programs that employ force-directed placement methods to arrange frequently-used words into relational clusters. Node size corresponds to word frequency. The connecting lines indicate strength and proximity of relationships between words. The remainder of this section describes this process in more technical detail and may be skipped over by those uninterested in the technical details of the word-map construction.

I converted all of the core texts to lower-case and saved each as a DOS text file. I then used TextSTAT to build a word frequency list from the articles. By filtering to the most common words in each set of articles, the difference in size of the two databases became roughly normalized. Of the 10,417 words used in the solar cell articles, 293 were used more than 6 times. Of the 7,026 words used in the LED articles, 313 were used more than 4 times. The ratio of total words between the two databases (7,026/10,417=0.674) is about the same as the frequency ratio (4/6=0.667). I used this normalization technique for three topical word lists, using the program fulltext.exe[5] from Loet Leydesdorff at the University of Amsterdam to create a cosine-normalized word matrix, which essentially provides for a graphical orientation in which ultimately relevant words that are used together throughout the corpus of articles become physically closer in the graphical rendering and dissimilar words display farther apart. This corresponds to the cosine which is a maximum value when graphic vectors approach a parallel configuration (zero angle) and a zero value when arranged perpendicular to one another. I imported this matrix into the visualization tool Pajek[6] which allowed for further reduction by displaying only the most central words and links in the network and scaling the dataset, improving the visualization of the matrices. I formatted the maps using a Kamada-Kawai free association, a force-directed placement method for undirected graphs, which arranges formless distributions of points into relational clusters. In essence, this approach can be understood as a collection of word points connected by rubber bands – the stronger the correlation between the words within the corpus of articles, the thicker the rubber bands to pull those words together graphically. The program uses an iterative method so initially the graphic display of the words moves around but eventually settles into a kind of homeostasis, which is then captured in a two-dimensional graphical image.

The formulations, which are beyond the scope of this work, are introduced briefly below in the spirit of providing a springboard for those who may wish to expand and improve such renderings for the purposes of a fuller analysis. The approach outlined above is limited from a data perspective due to the fact that it relies on local minima, which can for these purposes be a lesser quality rendering than using global minima achieved through a Fruchterman–Reingold algorithm or multi-level approach. Also, the simple cosine-normalized word matrix is susceptible to an overestimation of similarity (Zhou & Leydesdorff, 2016). However, for the purposes of the visualization in Chapter 3, used for display rather than as a mode of analysis, the approach herein is

[5] http://www.leydesdorff.net/software/fulltext/index.htm

[6] http://pajek.imfm.si/doku.php

believed to be sufficient given the resources at hand for this work. Nevertheless, these limitations to this combination cosine-normalized word matrix and Kamada-Kawai force-directed placement method may be appropriate issues to address in future research.

For those interested in this data analysis where x_i and y_i are vectors, the fundamental cosine matrix is formulated as:

$$\text{Cosine}(x,y) = \frac{\sum_{i=1}^{n} x_i y_i}{\sqrt{\sum_{i=1}^{n} x_i^2 * \sum_{i=1}^{n} y_i^2}}$$

An alternative is to use an Ochiai coefficient as a similarity measure (Zhou & Leydesdorff, 2016) where c_x is the count (sum) of occurrences of x and c_{xy} the count of the co-occurrences of x and y. The Ochiai coefficient is formulated as:

$$Ochiai(\text{x}, \text{y}) = \frac{C_{\text{xy}}}{\sqrt{C_{\text{x}}\ C_{y}}}$$

More on this approach can be found in Zhou and Leydesdorff (2016).

3.2 Technical versus romantic description

If you are looking for romance, then you'd better *produce* energy rather than *conserve* it. During the energy shock journalists tended to wrap solar cells in romantic language and frame LEDs in impersonal technical terms. Writers associated LEDs with "geeks" or "geeky" activity. One story in the corpus reported on MIT students employing LEDs for a dance floor in a piece entitled "How Geeks Get Down" (Mone, 2006). Another covered how "another geek fashion accessory has gone mainstream," which detailed the launch of LEDs in Walmart stores by interviewing Peter Steel, global director of lighting products for Rayovac: "Quite a few Walmarts sold out in the first week. It surprised us…the research we did is consumers don't understand the technology" (Boutin, 2002). And indeed magazine writers felt obligated to explain the technical operation of LEDs in great detail. They commonly focused on physical qualities of the devices using dry technical language. One piece suggested that readers see LEDs as part of a principally technical lineage "the real potential of light-emitting diodes comes from their kinship to digital electronics. As diodes, they're closer in design to a Pentium chip than to the incandescent bulb that dates back to the 19th century and Thomas Edison" (Boutin, 2002).

By contrast, none of the science writers associated solar cells with geeks. Rather, they pursued stories of adventure and acumen. "Favorable winds weren't the only thing that helped Swiss psychiatrist Bertrand Piccard and co-pilot Brian Jones pull off the first nonstop round-the-world balloon flight in 1999," wrote Michael Stroh (2004) for *Popular Science Magazine*. "The trip also required burning nearly four tons of propane fuel, a fact that never sat well with the environmentally conscious adventurers. So now Piccard has dreamed up a greener—and far gutsier—aviation milestone to conquer: circling the globe in a solar-powered plane. 'It would be the purest way to fly,' he says" (p. 40). Frequently journalists told success stories of solar entrepreneurs accompanied by visual renderings of their projects.

In addition to these qualitative differences, the following semantic maps display how technical descriptions of LEDs (Figure 3.2) were both 1/3 larger and more interconnected than the technical discussions of solar cells (Figure 3.3).

Figure 3.2: Journalists use mundane technical descriptions to describe energy reduction technologies

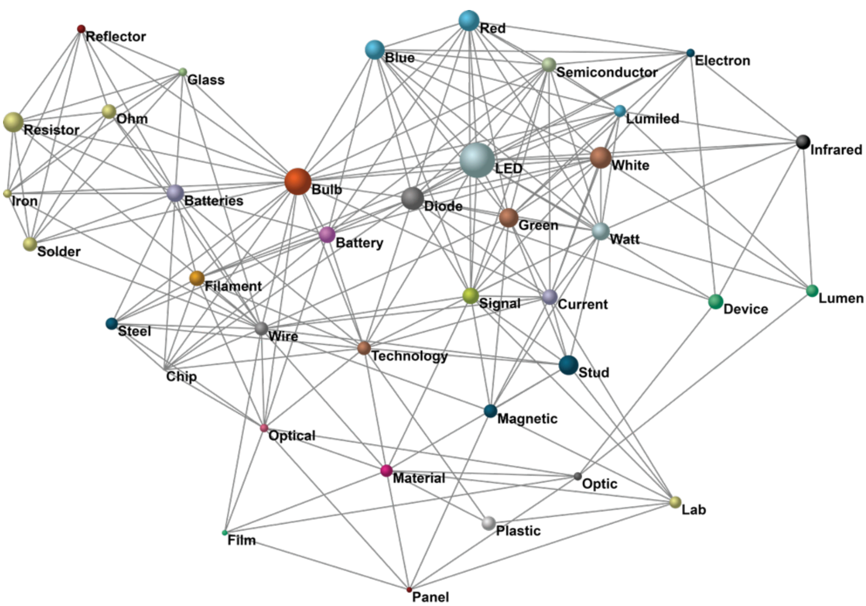
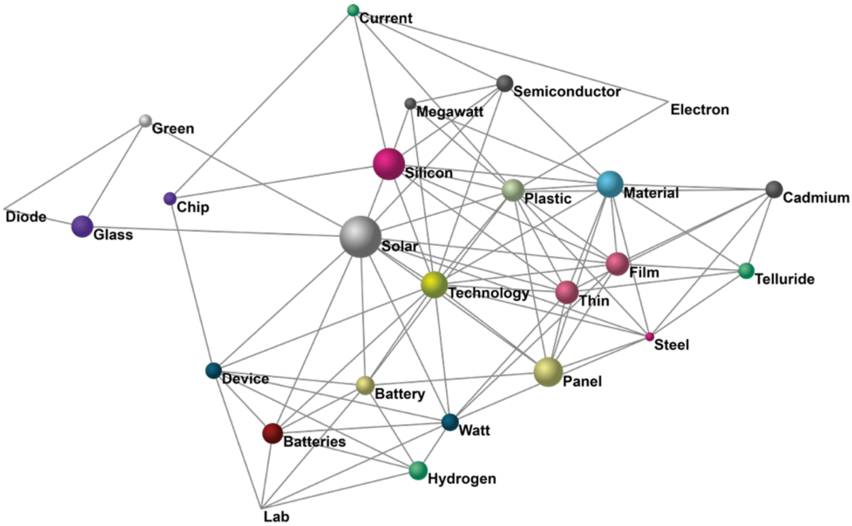


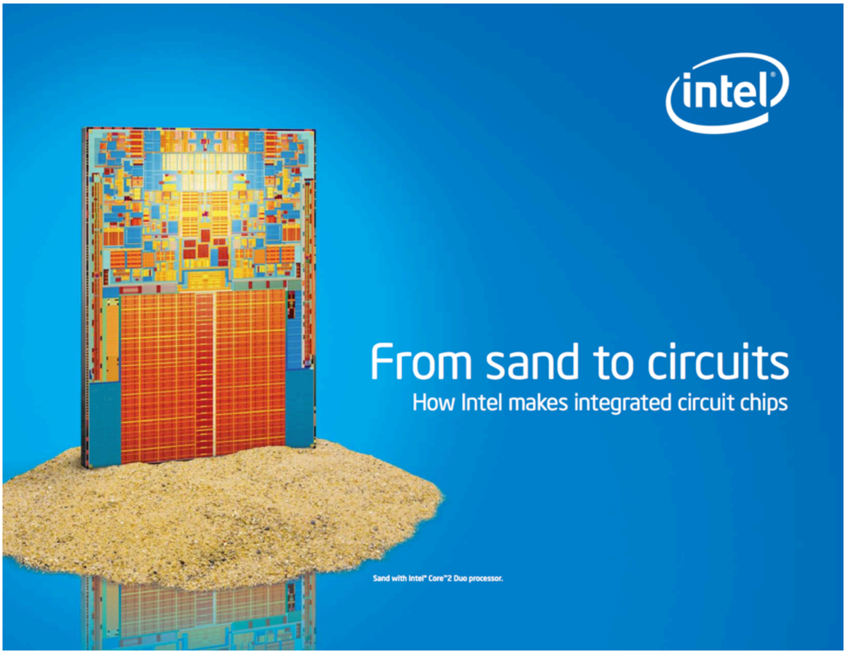
Figure 3.3: Journalists use roughly one-third less technical description when describing energy production technologies



Character-driven features typically center on people who are eager to present their green industry in a favorable light – usually business leaders, public figures, or others who viewers see as credible. Beder (2004) claims that this "gives powerful people guaranteed access to the media no matter how flimsy their argument or how self-interested" (p. 210). In the effort to provide credibility, journalists may unknowingly give equal voice to views that are blatantly exaggerated, have already been widely discredited, or are given little credence by those more familiar with the topic. Technical descriptions are more likely to uncover the grim realities of industrial production, while character-driven features float above such unsavory details. Silicon solar cells and integrated computer chips both arise from a similar process in which large polysilicon crystals are purified, grown, and cut into wafers. Numerous reports identify the raw material for this process as simply "beach sand," one of the most abundant materials on earth, giving the impression that the natural material for these components is simple, non-toxic, and virtually inexhaustible. But more interesting, is that as we move up the knowledge tree, this clumsy misrepresentation becomes more sophisticated. The National Renewable Energy Laboratory (2012) is more careful to identify solar silicon as "an element found in sand," a semiotic association that is chemically correct. The computer chip manufacturer, Intel, published a pamphlet entitled "From sand to circuits," which shows common speckled beach sand as the basis for polysilicon manufacture but contains a far more cultured description in the text, which indicates a level of sophistication in order to wind around a direct attribution to beach sand.

However, solar manufacturers don't use beach sand (and, as far as I can tell from interviewing those in the industry, never have used beach sand due to its impurities which would be arduous to extract). Although there are various methods; foundries typically begin the solar polysilicon process by melting one part rare high-purity crushed mined quartz with two parts purified coke typically from bituminous coal, a far less romantic prospect (Goodrich et al., 2013). Numerous mainstream scientific publications, policy papers, and news sources have published articles associating solar cells with beach sand in various ways. It is more difficult to find expert sources identifying that the primary starting material used for solar cell production isn't beach sand, or even crushed quartz "sand" for that matter, but coal. In fact, we can see this coal legacy in any solar array. Quartz is white; it is the coal de-oxidation step that yields polycrystalline silicon metal, which is what gives solar cells their black sheen. The observation that solar cells are borne from coal is a material observation that does not fit our generally accepted clean energy narratives and so there is potential for value in not seeing this relationship. For years experts and media characterized China's dominance in solar cell components as a feat of increasing efficiency in both supply chains and the modules themselves. However, the best solar cells of the sort in wide production, identified by the National Renewable Energy Laboratories as "Champion Photovoltaic Modules," only increased in efficiency by about 5 percentage points over the past 30 years – from about 15% energy conversion efficiency in 1990 to 20% energy conversion efficiency in 2020. The Chinese solar dominance appears to be more closely linked to 1) an abundant supply of cheap coal, 2) large government subsidies for that coal and other natural materials, and 3) forced labor, which the United States government has characterized as slavery (the United States has historically used prison labor to build cheap solar instead). As in Ursula K. Le Guin's novella *The Ones Who Walk Away from Omelas,* there is a benefit to the beneficiaries in not seeing such relations. But unlike the residents of Omelas, who could pack up and flee, as a civilization already exploiting the farthest nooks of the planet to fuel an expanding interconnected human presence, we have nowhere to flee to.

Figure 3.4: Intel identifies sand as the material basis for circuits. Microchips actually arise from mixing a rare quartz with coke frequently derived from bituminous coal.



In this case, a pervasive ignorance about the actual source of silicon for solar cell production (mined quartz) and the actual principal starting material (coal) may not arise from oversight or ineptitude but from expertise. Intel, like numerous other technology proponents, visually identifies common beach or desert sand as the starting point for polysilicon production. However, in this case the associated text takes a more cautious approach. Note the text below the image in Figure 3.5. First, the heading reads, “A sandy start,” a slightly more askew reference to sand that is evidently casual. However, the written description then backpedals. The writer has carefully avoided simply identifying the beach sand in the image as the starting ingredient directly, instead naming silicon as the starting ingredient, and then following up by qualifying silicon as “the principle ingredient in common beach sand.”

Figure 3.5: Intel graphically identifies sand as the starting point for polysilicon production, giving the impression that the raw material for chip production is common, non-toxic, and virtually inexhaustible. Meanwhile, the text carefully avoids calling sand the starting ingredient, perhaps indicating a strategic crafting of ignorance that draws upon on technical expertise rather than subverting it.

Sand → Purified silicon ingot → Wafer sliced from ingot and polished → Processed wafer → Completed die from finished wafer

The "recipe" for fabricating a chip varies depending on the chip's proposed use. Intel uses a variety of ingredients and performs as many as 300 steps with chemicals, gas, or light to complete fabrication.

A sandy start

It all starts with *silicon*, the principal ingredient in common beach sand. Intel builds chips in batches on *wafers* made of ultra-pure silicon. Silicon is a *semiconductor*. This means that unlike insulators such as glass (which always resist the passage of electrons) or conductors such as copper (which generally let electrons pass through), silicon can be altered to be a conductor or an insulator. Silicon is a good choice for making wafers because it is abundant, its oxide is a good insulator, and the industry has decades of experience working with it.

To make wafers, silicon is chemically processed so that it becomes 99.9999% pure. The purified silicon is melted and grown into long, cylindrical *ingots*. The ingots are then sliced into thin wafers that are polished until they have flawless, mirror-smooth surfaces. When Intel first started making chips, the company used 2-inch-diameter wafers. Now the company uses primarily 12-inch, or 300-millimeter (mm) wafers; larger wafers are more difficult to process, but the result is lower cost per chip.

Layer by layer

Intel uses a photolithographic "printing" process to build a chip layer by layer. Many layers are deposited across the wafer and then removed in small areas to create transistors and interconnects. Together, they will form the active ("on/off") part of the chip's circuitry plus the connections between them, in a three-dimensional structure. The process is performed dozens of times on each wafer, with hundreds or thousands of chips placed grid-like on a wafer and processed simultaneously.

Silicon, the principal ingredient in beach sand, is a natural semiconductor and the most common element on earth after oxygen.

7

These differences between visual and formal written descriptions of silicon appear frequently in the literature about solar cells. Visually we see beach sand. The written descriptions, interviews, and narrations often contain more careful references to sand, perhaps hedged with a qualifier or more glancing attributions. Finally, as we work up the chain of expertise, to academic texts and technical papers, we discover the most ornate representations, which incorporate sand's abundance metaphors into descriptions of silicon. An unknowledgeable person would be unable to orchestrate such carefully crafted language combinations perhaps indicating that we are witnessing the results of an instrumental applied ignorance that draws upon on technical expertise rather than subverting it. This more refined role of applied ignorance arising from expertise differs from Veblen's concept of "trained incapacity," which refers more to inadequacies in judgment as circumstances change. Rather what we witness here is a more cultured form of ignorance that is self-serving to the disciplinary field and appears to be enabled at least by physical displacement (the material effects occur far from the lived experience of readers so it is difficult or impossible to check up on claims), disciplinary isolation (scientific and policy expertise is often separated from manufacturing expertise), moral caution erosion (descriptions may be technically correct and offer plausible deniability in context), and what I would term a prestige motive, which includes not just a profit motive but also an ego-protective denial that enculturates an emblematic sense that one is fighting the just war. We shall consider several related examples in coming chapters to add more color to this description.

3.3 Mapping productivist expectations and promises

How else might energy users benefit from clean energy storylines? Governments frequently craft long-term predictions of energy use by extrapolating from past growth. Subsequently, firms evoke these predictions to prod investors to support fuel exploration, pipeline construction, and other productivist undertakings. Alternative energy companies have historically done the same. Once firms build out new energy supply, energy becomes more affordable and available; energy consumption increases and the original predictions come true. Numerous actors and factors hold the self-fulfilling prophecy together. Powerful energy lobbies promote their productivist inclinations in the halls of government. A consumer-driven public sops up any excess supply with a corresponding increase in demand. And since side effects are often hidden or displaced, the beneficiaries can continue at the expense of others who are less politically powerful, or who have not yet been born (see National Research Council, 2010).

Where does this leave expectations for energy reduction strategies? At the beginning of the energy price shock in 2003, LED bulb efficiencies were rapidly increasing and installed costs were dropping. In contrast, solar cell installed costs and efficiencies were comparatively flat (Zehner, 2012). We might expect journalists to have been excited about the trends in LEDs in comparison to solar cells but they weren't. Mainstream media outlets framed LEDs in terms of present practicalities, reviewing their use in flashlights, automobile headlamps and other mundane devices already in production. Journalists often cited past growth in LED efficiency but few projected those gains into the future or outlined possible scenarios for the technology. On the other hand, journalists eagerly imagined possible futures for solar technologies, using anticipatory language that framed the solar industry's promises as reasonable starting points for investment and attention.

Writing for WIRED magazine, Glasner (2006) wrote:

> *"Entrepreneurs promise that soon solar-energized 'power plastic' will radically extend the battery life of laptops and cell phones. Ultra-cheap printed solar cells will enable construction of huge power-generating facilities at a fraction of today's costs. And technologies to integrate solar power-generation capability into building materials will herald a new era of energy-efficient construction."*

Glasner then interviews a solar proponent for predictions about his field:

> *'These technologies look incredibly more real than they did five years ago,' said Dan Kammen, founding director of the Renewable and Appropriate Energy Laboratory at the University of California at Berkeley. Kammen predicts solar sources, which today produce less than 1 percent of power consumed nationwide, could eventually meet one-fifth of U.S. energy demand...In the meantime, solar startups entice investors with visions of clean, low-cost, energy-generating capability bundled into a range of products, from building materials to cell phones* (Glasner, 2006).

This excitement echoes a 1949 *Scientific American* article, which reviews industry expectations that solar cells will become "economically significant within a decade," and help double U.S. energy supply ("Energy resources," 1949). In 1956, the magazine estimated that "houses heated and cooled by solar energy can be expected in the next few years" (Tabor, 1956, p. 97). Following the Arab oil embargo, a 1976 feature article began with disbelief "that Americans should not be concerned about their supply of energy" since the new fabrication techniques were making solar cells "economically competitive" (Chalmers, 1976, p. 34). For quite some time, solar energy technologies have had this sort of a bright future. In my research, such promising language appeared twice as often in journalistic coverage of solar cells compared to that of LEDs (Figures 3.6 & 3.7).

Figure 3.6: Journalists use limited promising language when describing energy-reduction futures

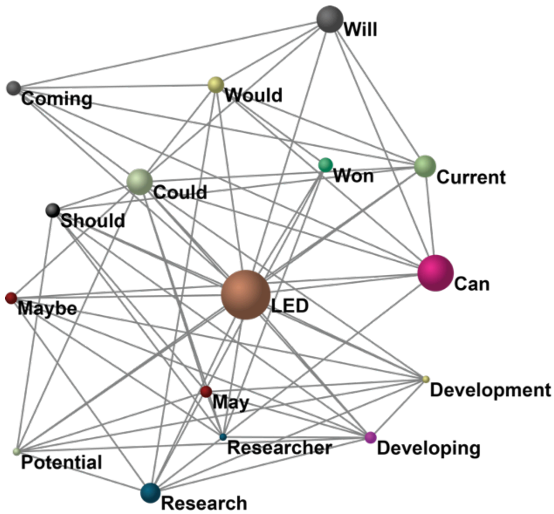
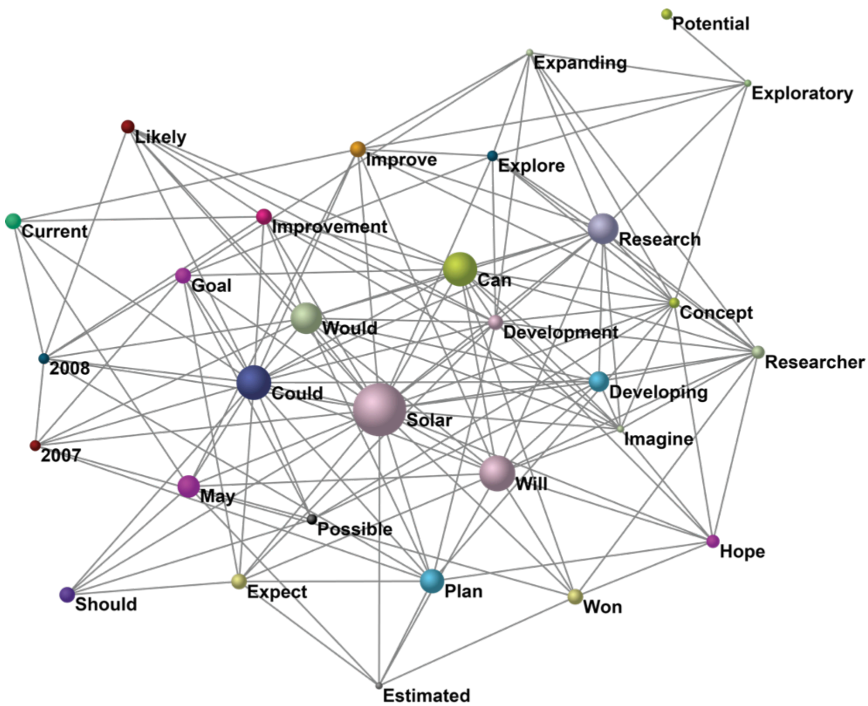


Figure 3.7: Journalists use roughly twice the promising language to describe energy-production futures



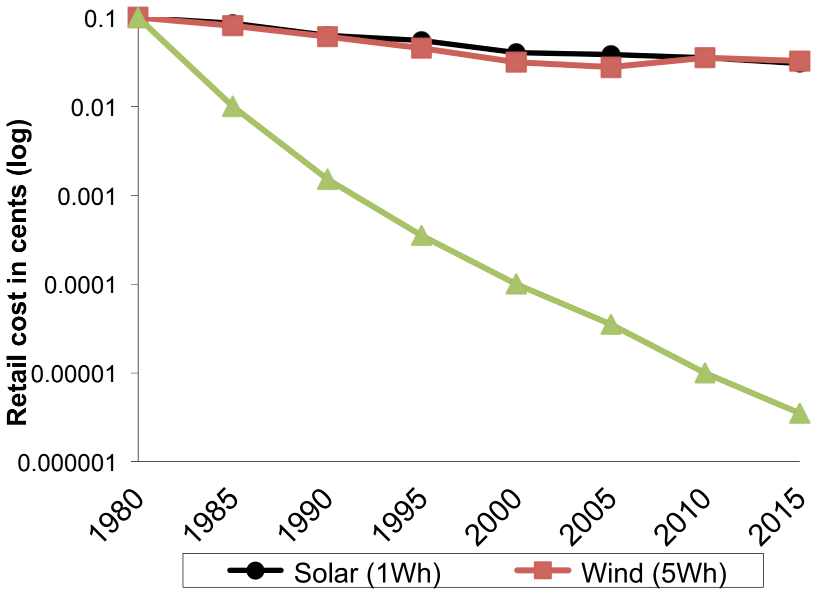
Early-stage technology fields, where no physical products exist, often run principally on promises. Stories about these technologies, rather than the technologies themselves, can organize investment and development (Robinson, 2014; Robinson, 2019). As we have seen, journalists and scientists frequently focus on the claim that prices of solar technical components have been declining. They rarely identify that most of the cost of an installed solar system goes toward low-tech expenditures for labor, insurance, and maintenance as well as materials such as concrete, copper, and aluminum, which remain stubbornly expensive and will presumably remain pricey into the future because they rely on vast quantities of dense fossil fuel for their manufacture (Prieto & Hall, 2013). To what extent does the focus on "technical innovation" obscure more rigid low-tech limits? Secondly, as introduced earlier, the United States, China, Germany, and other countries heavily subsidize solar cells. Solar subsidies increased dramatically in response to the 2003-2008 energy crisis and by 2011 the solar industry received at least $25 billion in subsidies, meaning subsidies alone equated to about twenty times the wholesale rate of conventional electricity per resulting MWh (IEA, 2012). The hope is that subsidies will amortize over 20-30 years of production but even then they remain substantial. And, because of interest rates on debt, such financing presumably relies on overall economic growth and in turn growth in natural material extraction, most notably, fossil fuels, which yield a high energy return on energy invested (EROI) (Murphy & Hall, 2010; Palmer, 2014). Since subsidies can clearly make solar costs, and subsequently energy inputs, appear far lower than they actually are, why do researchers and journalists typically leave subsidies out of their cost reporting, or otherwise neglect to tally a full accounting of them? Similarly, why are green tech material imports from abroad, with their embodied minerals, energy, labor, and ecological impacts, not treated as energy laundering?

In a related and notably rare critique, the New York Times reported in 2013 that defective panels are plaguing the solar industry, offsetting up-front savings with higher replacement costs (Woody, 2013). An industry study of 785 panels at two large solar installations in Spain reported a 16.2% defect rate after two years (Coello, 2011). A study of 30,000 panels in Europe found that 80% were underperforming (Woody, 2013). Why do researchers and reporters generally present data reported by the solar industry rather than these types of field measurements?

Most importantly, journalists and academic researchers rarely consider how the quality of energy from solar cells differs from that of fossil fuels, which is dense, storable, portable, fungible, and transformable, as introduced in Chapter 2. There, we reviewed the common practice of comparing a dispatchable energy to intermittent energy within the same chart as an example of assumptive ignorance. To expand on that point here, solar and wind energy is diffuse, so the systems to capture it must be large and therefore material intensive. Secondly, solar and wind output is not storable without dedicating yet another round of fossil fuels to build redundant supply or energy storage systems such as batteries. Third, the resulting stored energy is still not easily portable. For instance, the 435-pound, 5.5 ft. long Chevy Volt battery, when fully charged, carries the energy equivalent of just a single gallon of gasoline weighing six pounds. Finally, unlike fossil fuels, solar and wind systems and their byproducts are not transformable for use in smelting, fertilizers, pharmaceuticals, and other products necessary to support the labor that alternative energy proponents claim to disproportionately employ. Journalists, academics, and policy analysts alike overwhelmingly fail to consider whether solar and wind systems yield the quality of energy necessary to mine, smelt, and manufacture them and the systems that support them, succumbing to a process of categorical alignment, in which the disparate categories are forced into congruence in order to cobble together actionable knowledge (Epstein, 2012). And in creating this knowledge, it becomes valuable to ignore that energy firms do not, and cannot, use solar and wind energy to create solar cells and wind turbines. Consider, for instance, the *chemical* role that coal plays in iron smelting for wind towers or the dense fuels required for extracting high-tech metals – these processes employ carbon, which cannot easily be replaced with just electrical power. Similarly, a kilowatt-hour of baseload power is incommensurate with a kilowatt-hour of intermittent solar or wind power, which require batteries or other forms of power conditioning, greatly affecting both their cost and lifecycle energy footprints – often by an order of magnitude (Joskoaw, 2011; Energy Information Administration, 2016; Tverberg, 2020). Still, experts routinely compare kilowatt-hour outputs of these power technologies side by side. This structural assumptive ignorance obscures a dangerous incommensurability of numbers facilitating political support for feed-in tariffs and mandates for intermittent power that reaps havoc on grids without enough of the expensive and fossil-fuel-intensive storage infrastructure to absorb it.

This incommensurability can also manifest semiotically, when energy technology proponents indulge in rich descriptions and associations that might seem entirely implausible were they to occur outside the protective halo of green energy symbolism. Espeland (2007) aptly considers how measurements can create social worlds and we may extend that faculty to mis-measures as well. Take for instance a *New York Times* article, which states, "A link between Moore's law and solar technology reflects the engineering reality that computer chips and solar cells have a lot in common" (Zachary, 2008). This symbolic link between solar cells and Moore's law is widespread and another case of instrumental ignorance. Former U.S. vice president and energy industrialist Al Gore seems to understand that the association is not quite right, but makes it anyway. "The cost down-curve is not quite as steep as Moore's law but it's real steep," Gore said in an interview, "that's the part of the computer chip revolution that was so cool - that's happening with photovoltaic energy and wind energy now" (Gore, 2013). Numerous media outlets industriously evoke the Moore's Law association. But, we might have a difficult time finding a single physicist to agree. Were solar technologies following Moore's Law in terms of cost or performance during the period leading up to, during, or after the 2003-2008 energy crisis? No, no, and no, according to cost reporting from the industry itself, shown in Figure 3.8.

Figure 3.8: Despite the common association, wind and solar technologies have not historically adhered to Moore's Law according to data from the associated industries (Intel, NREL, and Solarbuzz)



Solar proponents don't offer data, statistics, figures, or any other explanation for the association to Moore's Law beyond the simple comparison itself – a semiotic hit and run. One question might be this; to what degree and in what ways do researchers succumb to unacknowledged emotional, cultural, financial, or technophile bias in crafting their alternative energy inquiries? To what degree and in what ways might researchers know that some representation isn't quite right but succumb to self-deception, positive thinking, or a prestige motive in order to craft various forms of ignorance in the service of valorizing what they know to be true and just (or profitable)?

3.4 Productivism becomes a climate change solution

The third and most striking media representation is the association of solar cells, but not LEDs, with climate change mitigation. During the energy shock, journalists presented solar cells as a "clean" alternative that could reduce greenhouse gas emissions. They featured companies employing solar cells as part of their socially-responsible planning to show that the technology is entering mainstream use. In reporting on LEDs, journalists discussed device efficiency but less frequently linked those energy savings to climate change or greenhouse-gas reductions. They rarely associated LEDs with pollution reduction from power plants. Also notably absent were colorful stories about companies using LEDs to reduce their ecological footprint.

Figure 3.9: Journalists rarely frame energy reduction as a solution to climate change

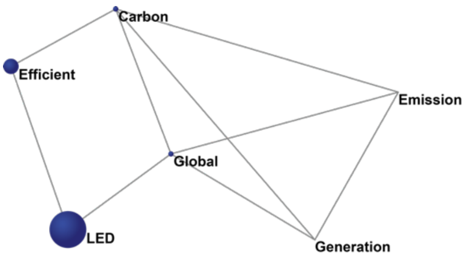
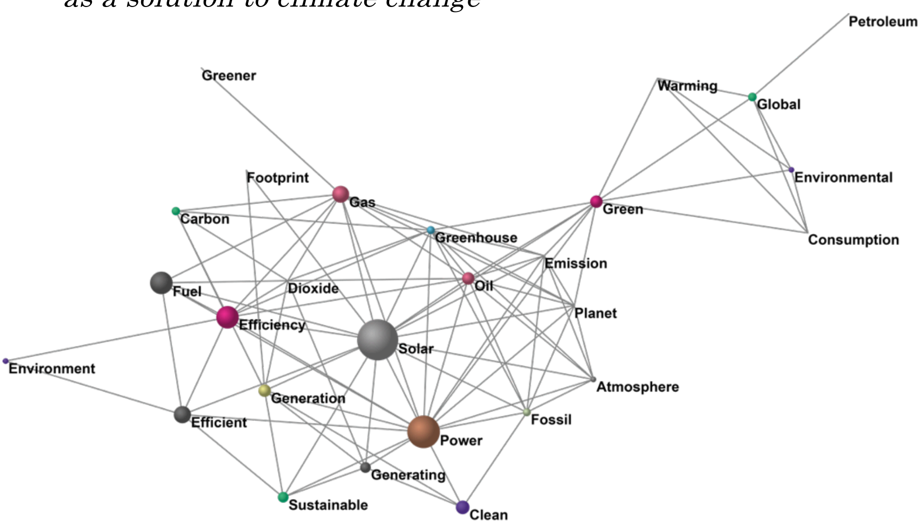


Figure 3.10: Journalists frequently frame energy production as a solution to climate change



In effect, readers are presented with the idea that the *priority* path to mitigating carbon is not through reducing consumption but through increasing production, using seemingly alternative means. We might assume that this is more or less acceptable so long as solar cells, at minimum, (1) offset fossil fuel use, and (2) produce significantly more net energy than is required for their construction and deployment. Media, as well as the vast majority of governmental and academic researchers *assume* that they do both. However, there is an emerging problem with these assumptions – there's scant material or theoretical evidence to support these assumptions (Capellán-Pérez, De Castro & González, 2019; Dunlap, 2018; Ferroni & Hopkirk, 2016; Hornborg, Cederlöf & Roos, 2019; Rees, 2019; Tverberg, 2020; York, 2016). Chapter 6 reviews how solar cells appear to be subject to a price-tag predicament. In short, where do the high costs of solar cells accrue, if not ultimately to fossil fuels via profit, materials, and labor? Like other industrial commodities, solar cells rely on dense fossil fuels for manufacturing, financing, and labor (workers in turn use fossil fuels for constructing shelter, transportation, fertilizer for food, and so forth) (Prieto & Hall, 2013; Ferroni & Hopkirk, 2016). Do the high costs of installed solar systems merely indicate fossil fuel consumption through alternate means? York (2012, 2016) reviews 50 years of energy data, finding that non-fossil energy, such as solar, wind, nuclear, and hydro, have not equally offset fossil fuel use in practice, concluding: "The common assumption that the expansion of production of alternative energy will suppress fossil-fuel energy production in equal proportion is clearly wrong" (York, 2012, p. 443). Perhaps part of this is due to the quality issues reviewed earlier, but we might also consider the history of hydropower in the United States. In 1950, dams filled roughly a third of U.S. electrical demand. Subsidized hydropower helped keep electricity costs low and demand subsequently increased across the board. Utilities filled that demand by building more fossil fuel power plants, not fewer. Dams have multiplied since 1950 but hydropower now fills just seven percent of the nation's electricity grid.

This may be an energy boomerang effect, as I propose in Chapter 7, which could conceivably occur in any expanding economy to varying degrees (Zehner, 2012b; Zehner, 2013c). In an energy boomerang, subsidized energy induces a downward pressure on energy costs. Demand relatively expands, bringing the economy right back to where it started, with constrained supply coupled with sustained demand. That demand could manifest in electrical demand or through demand for products, services, and imports. Here we see another parallel with the work of Schwarz-Cowan (1983) who identifies that the development of time-saving household technologies, although more productive and less laborious, did not reduce the demands on most housewives. Perhaps the harder we throw new power into the grid, the harder we risk demand coming back to hit us on the head? In an expanding economy, are larger solar arrays, taller wind turbines, and larger fields of biofuel crops just ways of throwing the boomerang harder? If they do indeed produce net energy, they may be. If they don't, then subsidizing the underlying industrial processes for their creation could yield similar rebound effects.

3.5 Selective knowledge, objectivity, echo chambers and the EGA

Objectivity in journalism is frequently, yet mistakenly, understood as truth. Facts are elusive, and news organizations understand that attempting to sell them directly would be sheer folly. Journalistic objectivity is not so much a rendering of truth as much as it is an attempt to accurately convey what others believe to be true. In order to achieve this rendering, experienced traditional journalists may instruct novice journalists to keep their own beliefs and evaluations to themselves through a conscious depersonalization (Nelkin, 1987; Mindich, 1998). Second, traditionally-schooled mentors may instruct new writers to aim for balance, or field "both sides" of a controversial subject without showing favor to one side or the other (Nelkin, 1987; Mindich, 1998). The news industry has historically accepted this framework as the best way to go about reporting on issues and events. Nevertheless, this truth-proximating strategy carries certain peculiarities (Holiday, 2013).

For example, news editors have tended to judge stories supporting the status quo as more neutral than stories challenging it, which they understand as containing bias or being opinion laden (Mindich, 1998). Investigations that present empirical evidence and consider unfamiliar alternatives are not as valued as the familiar "balance of opinions." As a result, journalists reduce energy debates to a contest between alternative energy technologies and conventional fossil fuels. Pitting one method of energy production against another effectively sidelines energy *reduction* options, as if productivist methods are the only choices available (Zehner, 2012). These journalistic dichotomies also reduce apparent options to an emaciated choice between Technology A and Technology B. This leaves little space for nontechnical alternatives. It also misses negative effects that both Technologies A and B share in common (Zehner, 2012). Finally, pitting alternative-energy technologies against fossil fuel reinforces the impression that their qualities are comparable or that increasing alternative-energy flows will correspondingly decrease fossil fuel consumption.

In one study of journalists during the period of analysis, eight in ten claimed news rooms dedicated insufficient attention to complex issues such as global energy production, use, and related side effects (Kohut, 2008). Understaffed news rooms increasingly initiated stories using material distributed by public relations firms and corporations – rather than investigative work (Kohut, 2008). Energy firms frequently provide journalists with videos, photographs, and computer renderings along with enticing hooks and in some cases directly fund the news organizations covering their field. The drive for entertainment leaves less space to cover background, contextual fundamentals, or the structural origins of increasing energy consumption. These factors help explain the abundance of articles touting new green gadgets, which are frequently rewritten press releases from companies or researchers promoting their products and eager to attract attention (and funding) for their often half-baked schemes.

Time pressures and streamlining media operations force journalists to increasingly rely on quotes and comments from a short list of contacts, usually government, industry, public figures, or other sources that viewers see as credible. Beder (2004) claims that this "gives powerful people guaranteed access to the media no matter how flimsy their argument or how self-interested" (p. 210). In the effort to provide credibility, journalists may unknowingly give equal voice to views that are blatantly exaggerated, have already been widely discredited, or are given little credence by those more familiar with the topic. In their book *Merchants of Doubt*, Oreskes and Conway (2010) show how over a period spanning decades, oil and industry groups effectively convinced the public that a scientific controversy surrounded climate change when, in fact, there was little disagreement. However, in later works Oreskes and Conway (2014) unwittingly succumb to the very prejudice they so expertly warn us against.

Oreskes and Conway (2010) begin their initial exploration by considering how consensus among climatologists actually began to solidify in the 1970s. In 1988, researchers organized the Intergovernmental Panel on Climate Change IPCC to assess the risks associated with human-induced climate change. That same year, NASA reported to Congress that climate change was occurring and that it was caused by humans. After years of research, the IPCC stepped forward to agree with NASA scientists.

Feeling threatened, several oil companies and other large corporations joined forces to fund advertising campaigns, foundations, and organizations such as the American Enterprise Institute, the Global Climate Coalition, and the George Marshall Institute, in order to attack the credibility of scientists studying climate change and to frame climate change as a scientific "dispute" rather than a consensus. These organizations hired many of the same public relations and legal consultants who had earlier ridiculed doctors for warning about the risks of cigarette smoke.

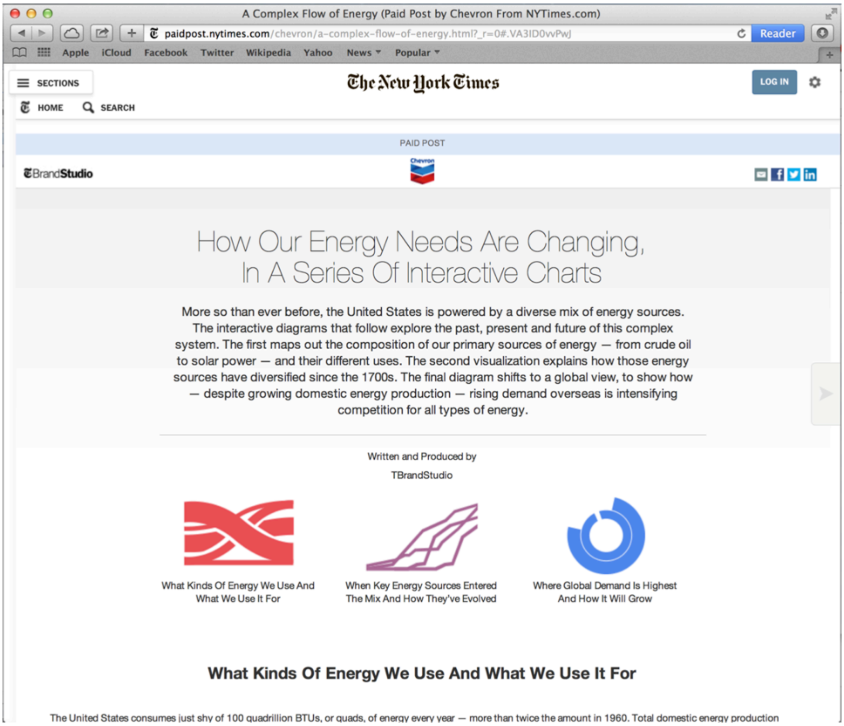
In the early 1990s, these skeptics organized test markets to ascertain the most effective ways of producing "attitude change." When they discovered that people tended to believe scientists over politicians or corporations, they test-marketed names of scientific front organizations. Once set up, these front organizations would produce reports that questioned climate change. They distributed their arguments via pamphlets, mass media, and the Internet, rather than publishing in peer-reviewed journals. Internal documents from these organizations reveal that they found radio ads to be the best way to influence "older, less educated males." For "younger, low-income women," they selected magazine ads. They even test-marketed the spokespeople for their believability. By the early 1990s, these organizations had launched a full-fledged public relations tour to frame climate change as both a controversy and a topic that required more research before consensus could be reached. They ensured that journalists would have ample opportunity to "balance" the views of climatologists with those of the skeptics, even if the naysayers could not speak with scientific authority themselves.

The public relations campaign proved a magnificent success. It greatly influenced media coverage and swayed public opinion. In 2006, a *Time Magazine* poll showed that a majority of Americans believed global temperatures were rising. Yet 64 percent also believed that scientists were still busy making up their minds on the matter. And in fact, the year Oreskes and Conway's book was published, a FOX news employee leaked an internal email from the Washington bureau chief that instructed, "Refrain from asserting that the planet has warmed (or cooled) in any given period without IMMEDIATELY pointing out that such theories are based upon data that critics have called into question. It is not our place as journalists to assert such notions as facts, especially as this debate intensifies" (see Jerónimo et al, 2013).

Even while they present an unflinching account of how conservative moneyed interests are able to aggregate a narrative, drawing upon their own echo chamber, Oreskes and Conway tragically overlook, however, in subsequent works, including a book (Oreskes & Conway, 2014) and a film (Kenner, 2014), that among liberal-leaning moneyed interests, the exact same process may very well exist. Oreskes and Conway expose a seemingly bottomless pit of manufactured and self-serving ignorance and then fall into it themselves by offering their uncritical allegiance to renewable energy in the fight against the "carbon combustion complex" (Oreskes & Conway, 2014). The perceived enemy of renewable energy is fossil fuel and, of course, the rhetoric of climate change skeptics. In a social functionalist explanation, Kenner (1968) identifies that once a hoax is unraveled, seen for what it is by observers, it can serve a social purpose of reifying the value of the "wronged" entity. In other words, a sense of "they were trying to deceive us, so that must mean our underlying motives are actually right." Of course, as emancipatory as it may feel, just because we have been wronged, doesn't necessarily mean we are in the right.

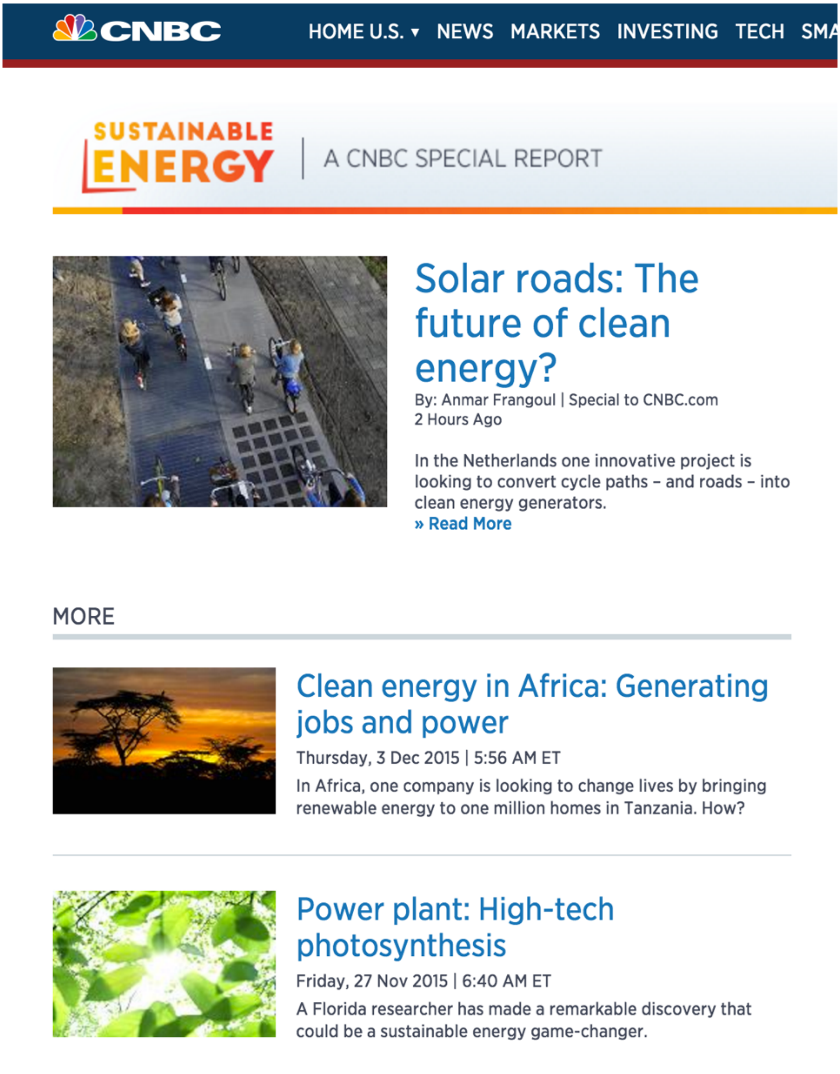
The mechanisms of support for high technology energy products is remarkably similar to the arrangements initially outlined by Oreskes and Conway (2010). For instance, some media outlets will directly reprint special interest group "content" under their own masthead. The Detroit Free Press has directly published environmental materials prepared by a branding firm called "Issue Media Group," which is dedicated to "creating new narratives" that promote growth and investment (*Issue Media*, 2014). The New York Times published an interactive chart (see Figure 3.11), promoted throughout its website, which was produced in-house and funded by Chevron as well as a renewable energy video series sponsored by ExxonMobil (T Brand Studio, 2014; 2018).

Figure 3.11: The New York Times works with companies such as Chevron, ExxonMobil, and Goldman Sachs to produce content for readers.



The source of funding for such coverage is frequently less visible or even very difficult to trace. CNBC has produced a “Sustainable Energy Special Report” that upon further investigation is sponsored by a French oil, gas, and chemical multinational. The series leads with gee-wiz stories about solar cells and eventually culminates with articles promoting the biofuels industry – both being products that the firm produces.

Figure 3.12: CNBC created a "Sustainable Energy Special Report" under its own masthead that was actually sponsored by an oil, gas, and chemical conglomerate.



The online news organizations Alternet, Salon.com, and Truthout have published material written by "Global Possibilities," a special interest group funded in part by the oil company BP and a group of automotive and energy industrialists represented through The Energy Foundation (Global Possibilities, 2013). The special interest group "Inside Climate News," funded in part through The Energy Foundation, the Rockefellers, and other productivist interests, claims to publish through numerous media brands including the Associated Press, Bloomberg, Business Week, The Weather Channel, The Guardian, and the McClatchy Group, a conglomerate of 30 daily newspapers across the United States (*Inside Climate News*, 2014). Another media intermediary, Climate Desk, founded in part on the idea that existing journalistic "coverage is too often fixated on imperiled wildlife," distributes its largely energy productivist articles through Newsweek, The Atlantic, New Republic, Mother Jones, WIRED, Slate, The Huffington Post, Grist, and The Guardian as exemplified in Figure 3.13 (Zellers, 2010).

Figure 3.13: Newsweek, The Guardian, and other news outlets publish energy-related articles under their own masthead that are actually created in collaboration with unidentified interests, often philanthropic foundations chaired principally by titans of industry and banking.

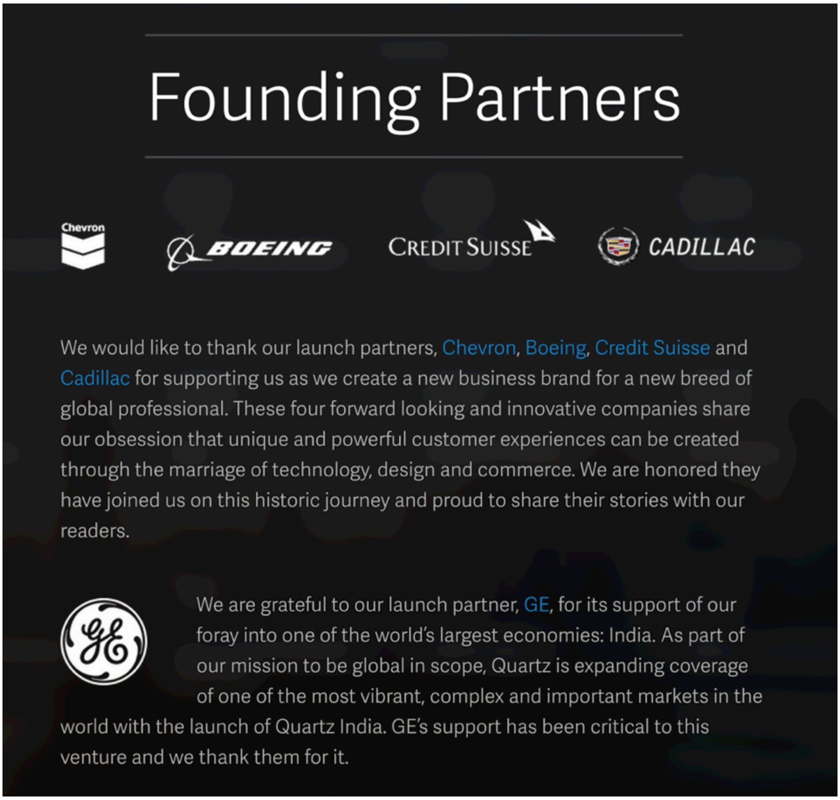
An organization called Climate Central, funded by Google, the weapons manufacturer Northrup Grumman, and a number of foundations headed by leaders of finance and industry, reveals its mode for using trusted local news broadcasters to bring viewers in for their messaging, stating:

> *"Research shows that meteorologists are trusted messengers on climate change. The majority understand that climate change is real and that the science of climate change needs to be communicated to the public. Unlike climate scientists, TV meteorologists have unparalleled access to their communities. Through Climate Matters, Climate Central provides regularly produced content on the relationship between weather and climate. Our team of data analysts, meteorologists, climate experts, graphic artists and journalists create graphics, text, animations, videos and research to aid TV weathercasters in presenting science-rooted climate information in clear, concise and relevant ways"* (Climate Central, 2016).

Climate Central claims the following media sources have featured its work: New York Times, The Washington Post, Financial Times, The Economist, ABC World News, CBS Evening News, NBC Nightly News, CNN, MSNBC, National Public Radio, Nature, PBS, The Weather Channel, The Atlantic, The Guardian, The Los Angeles Times, The Minneapolis Star Tribune, The Orlando Sentinel, The Miami Herald, The Chicago Tribune, The Baltimore Sun, AFP, La Presse.ca (Canada), El Nuevo Diario (Nicaragua, CD News (Taiwan), World Journal (China), Delhi Daily News (India), El Espectador (Colombia), La Prensa (Honduras), Le Devoir (France), Radio Habana (Cuba), Dominicanos HOY (Dominican Republic), servimedia.es (Spain), The Japan Times (Japan), The Sydney Morning Herald (Australia), International Business Times (India), Le Figaro (France), Telegraph (UK), and Die Welt (Germany) (Climate Central, 2019).

The media conglomerate Atlantic Media produces a quickly growing online platform named *Quartz*, which describes itself as "a guide to the new global economy for people in business who are excited by change" (Quartz, 2016). Although there is no disclosure on its articles regarding clear conflicts of interest related to its energy-related analysis, buried three levels down in the site it is possible to find that the platform was founded by Chevron, Boeing, Credit Suisse, Cadillac, and GE (see Figure 3.14).

Figure 3.14: Atlantic Media published Quartz, which appears to be an independent news outlet but was actually co-launched by industries with direct conflicts of interest with the outlet's reporting. Source: Atlantic Media



Claiming to be the most widely read source of environmental journalism, The Mother Nature Network publishes the website Treehugger. The Koch Brothers' paper and forestry products company Georgia Pacific was a founding partner of Mother Nature Network and also a member the Sustainable Forestry Initiative - along with Greenpeace, Dogwood Alliance, NRDC, Sierra Club, Rainforest Action Network, WWF, and Nature Conservancy. The consortium publishes sponsored content on Treehugger, including the article, shown in Figure 3.15 and Figure 3.16, entitled "7 ways to spot a healthy forest," which argues that a healthy forest is one that is being logged to "prevent overcrowding" and is economically "productive."

Figure 3.15: Treehugger readers may think they are reading journalism when they are actually reading carefully crafted industry talking points in article form. Mainstream environmental groups, in this case Greenpeace, Dogwood Alliance, NRDC, Sierra Club, Rainforest Action Network, WWF, and Nature Conservancy, often funded by the same interests, frequently help facilitate the deception. This article argues that a healthy forest is one that is being logged to "prevent overcrowding" and is economically "productive." Source: Treehugger

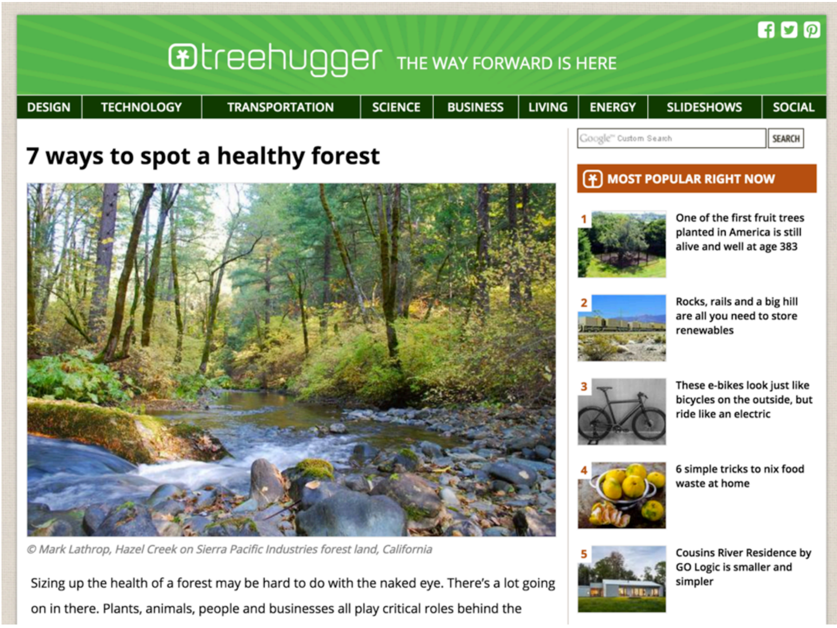
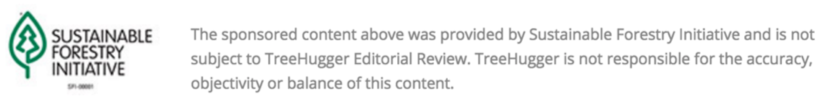


Figure 3.16: This footnote at the bottom of the Treehugger article identifies the piece as sponsored content, not independent writing or journalism in the traditional sense. Source: Treehugger



Special interest groups commission their articles from within a sphere of private, typically business, interest, often in coordination with philanthropic foundations led principally by titans of finance and industry, who supply the funding (see Figure 3.17). Readers and viewers have a difficult time distinguishing between such sponsored content and traditional independent journalism (Beder, 2004; Holiday, 2013).

Figure 3.17: A template showing how moneyed productivist interests fund intermediary media groups, in this case Inside Climate News and Global Possibilities, to prepare content for news brands that readers trust and see as independent, such as the Associated Press, Bloomberg, The Guardian, Alternet, Salon.com, Truthout, and the McClatchy newspaper group.

How might the public understanding of energy technologies differ if journalists instead wrote about the energy technology industry's reliance on natural material extraction and fossil fuels for smelting and fabrication or how wind and solar arrays require conventional power plants to stand alongside them, or storage mechanisms such as batteries, which require further rounds of fossil fuel and material extraction? Such considerations, as obvious as they may seem upon reflection, are conspicuously underrepresented in reporting on solar cells. Nevertheless, one notable article by journalist Chris Clarke (2016), shows the possibilities for analysis that appear when such considerations are taken into account. Like many other environmental journalists covering the 2016 protests at Standing Rock, North Dakota, Clarke followed activists opposed to the construction of a fossil fuel pipeline being built through the American Indian lands. However, he uniquely noted that activists "largely fall silent when renewable energy projects pose threats to Native culture." And he pointed out that some of the same groups protesting the pipeline were at the same time lobbying the Bureau of Land Management to allow desecration of sacred sites for solar energy development, quoting a Sierra Club representative as saying the site was "a pretty decent area to be what you might call a sacrifice area for solar." This opened the stage for Clarke to consider larger ecological justice implications, observing that "Native people and non-Native environmental activists are wonderful potential allies. Allies can and often do disagree. But if you support your allies only when their goals coincide with yours, and ignore or oppose them when they express concern that your objectives stand to do them damage, that's not an alliance. It's using those people to further your own aims, and not giving anything back." Clarke's method, one that draws upon some more traditional ideals of journalism, is rare in coverage of solar technologies and a reminder that energy coverage holds the potential to be critically engaging. The next chapter takes the opportunity to explore this possibility through practice.

Chapter 4: Developing electric vehicle questions

As mentioned earlier, this chapter is the first of four chapters presented as case manuscripts. This manuscript is designed as an application of how writers might bring into their writing the different sorts of questions presented in the previous chapters. Specifically, what can be learned from initiating a public and professional dialog that proposes a semiotic and material divide and acknowledges a potential role for non-knowledge in the process? How can such an analysis be structured and contextualized? What impacts might a consideration of non-knowledge have on the public understanding of energy technologies? Does this mode of analysis hold the potential to engage professional and lay audiences?

In 2013 the case manuscript that follows in section 4.1 was published in *IEEE Spectrum* the journal of the Institute of Electrical and Electronics Engineers and the largest journal read by electrical engineers globally. It is rare for *IEEE Spectrum* to publish papers with social scientific perspectives, but the editors agreed to a science-studies analysis for this topic. Similar to the next three chapters, this chapter was written with an informal, almost conversational tone. The goal was to form a social scientific analysis designed for practicing engineers who may not be familiar with social scientific theory. An analysis of the article follows in section 4.2. Section 4.3 at the end of this chapter contains a review of the paper's reception. The paper follows here in its entirety and can be viewed with the associated graphics and references at:
http://spectrum.ieee.org/energy/renewables/unclean-at-any-speed

4.1 Unclean at any speed

Last summer, California highway police pulled over pop star Justin Bieber as he sped through Los Angeles in an attempt to shake the paparazzi. He was driving a hybrid electric car—not just any hybrid, mind you, but a chrome-plated Fisker Karma, a US $100,000 plug-in hybrid sports sedan he'd received as an 18th-birthday gift from his manager, Scooter Braun, and fellow singer Usher. During an on-camera surprise gifting, Braun remarked, "We wanted to make sure, since you love cars, that when you are on the road you are always looking environmentally friendly, and we decided to get you a car that would make you stand out a little bit." Mission accomplished.

Bieber joins a growing list of celebrities, environmentalists, and politicians who are leveraging electric cars into green credentials. President Obama once dared to envision one million electric cars plying U.S. roads by 2015. London's mayor, Boris Johnson, vibrated to the press over his born-again electric conversion after driving a Tesla Roadster, marveling how the American sports coupé produced "no more noxious vapours than a dandelion in an alpine meadow" (Johnson, 2009). Meanwhile, environmentalists who once stood entirely against the proliferation of automobiles now champion subsidies for companies selling electric cars and tax credits for people buying them.

Two-dozen governments around the world subsidize the purchase of electric vehicles. In Canada, for example, the governments of Ontario and Quebec pay drivers up to CAD $8500 to drive an electric car. The UK offers a £5000 Plug-in Car Grant. And the United States provides up to $7500 in tax credits for people who buy plug-in electric vehicles, even though many of them are affluent enough not to need such a credit. The average Chevy Volt owner, for example, has an income of $170,000 per year (Munro, 2012).

California will boost the total credit up to $10,000 and Colorado, $13,500 - more than the cost of a brand new Ford Fiesta. West Virginia offers the sweetest deal. The state's mining interests are salivating at the possibility of shifting automotive transportation from petroleum over to coal. Residents can receive up to $15,000 for their electric car purchase and up to $10,000 toward the cost of a personal charging station. Corporations adding private charging facilities as a perk to their employees can receive a check for up to a quarter million dollars from the state.

There are other perks. Seven U.S. states open the high-occupancy lanes of their highways to electric cars, even if the car carries but a lone driver (McCarthy, 2008). Numerous stores offer VIP parking for electric vehicles—and sometimes a free fill-up of electrons. In Nevada electric cars are exempt from public parking meters. Mayor Johnson even moved to relieve electric-car owners from the burden of London's famed congestion fee.

Alas, these carrots can't overcome the reality that the prices of electric cars are still very high—a reflection of the substantial material and fossil-fuel costs that accrue to the companies constructing them. And some taxpayers understandably feel cheated that these subsidies tend to go to *the very rich. Amidst all the hype and hyperbole, it's time to look behind the curtain. Are electric cars really so green?*

The idea of electrifying automobiles to get around their environmental shortcomings isn't new. Twenty years ago, I myself built a hybrid electric car that could be plugged in or run on natural gas. It wasn't very fast, and I'm pretty sure it wasn't safe. But I was convinced that cars like mine would help reduce both pollution and fossil-fuel dependence.

I was wrong.

I have come to this conclusion after many years studying environmental issues more deeply and taking note of the questions we allow ourselves to ask as concerned citizens. Mine is an unpopular stance, to be sure. The suggestive power of electric cars is a persuasive force—so persuasive that answering a seemingly simple question, "are electric cars green?," quickly gets complicated. As with anything, the answer depends on whom you ask. Dozens of think tanks and scientific organizations have ventured conclusions about the environmental friendliness of electric vehicles. Most are supportive, but a few are critical. For instance, Richard Pike of the Royal Society of Chemistry provocatively determined that electric cars, if widely adopted, stood to lower Britain's carbon dioxide emissions by just 2 percent, given the nation's electricity sources (Pike, 2009). Last year, a U.S. Congressional Budget Office study found that electric car subsidies "will result in little or no reduction in the total gasoline use and greenhouse gas emissions of the nation's vehicle fleet over the next several years" (Congressional Budget Office, 2012). Others are more supportive, including the Union of Concerned Scientists. Its 2012 report on the issue, titled, State of Charge, notes that charging electric cars yields less CO_2 *than even the most efficient gasoline vehicles (Anair & Mahmassani, 2012). The report's senior editor, engineer Don Anair, concludes: "We are at a good point to clean up the grid and move to electric vehicles" (Anair, 2013).*

Why is the assessment so mixed? Ultimately because it's not just about science. It's about values, which inevitably shape what questions the researchers ask as well as what they choose to count and what they don't. That's true for many kinds of research, of course, but for electric cars, bias abounds, although it's often not obvious to the casual observer.

To get a sense of how biases creep in, first follow the money. Most academic programs carrying out electric-car research receive funding from the auto industry. For instance, the Plug-in Hybrid and Electric Vehicle Research Center at the University of California, Davis, which describes itself as the "hub of collaboration and research on plug-in hybrid and electric vehicles for the State of California," acknowledges on its Website partnerships with Nissan, BMW, and Chrysler-Fiat, all of which are selling or developing electric and hybrid models. Stanford's Global Climate & Energy Project, which publishes research on electric vehicles, has received more than $113 million from four firms: ExxonMobil, General Electric, Schlumberger, and Toyota (Stanford University, 2012). Georgetown University (Georgetown University, n.d.), MIT (MIT Electric Vehicle Team, n.d.), University of Michigan (University of Michigan, n.d.), University of Delaware (University of Delaware, n.d.), University of Colorado (University of Colorado Boulder, 2013), and numerous other schools also accept corporate sponsorship for their electric-vehicle research.

I'm not suggesting that corporate sponsorship automatically leads people to massage their research data. But it can shape findings in more subtle ways. For one, it influences which studies get done and therefore which ones eventually receive media attention. After all, companies direct money to researchers who are asking the kinds of questions that stand to benefit their industry. An academic who is studying, say, car-free communities is less likely to receive corporate funding than a colleague who is engineering vehicle-charging stations.

Many of the researchers crafting electric vehicle studies are eager proponents of the technology. An electric-vehicle report from the School of Environmental Affairs at Indiana University (2011), led by a former vice president of Ford, reads like a set of public relations talking points and contains advertising recommendations for the electric-car industry (that it should manage customers' expectations, so as to avoid a backlash from excessive claims). Even the esteemed Union of Concerned Scientists clad the executive summary of its electric-car report in romantic marketing imagery courtesy of General Motors and Ford, companies whose products it is evaluating. Indeed, it's very difficult to find researchers who are looking at the environmental merits of electric cars with a disinterested eye.

So how do you gauge the environmental effects of electric cars when the experts writing about them all seem to be unquestioned car enthusiasts? It's tough. Another impediment to evaluating electric cars is that it's difficult to compare the various vehicle-fueling options. It's relatively easy to calculate the amount of energy required to charge a vehicle's battery. It isn't so straightforward, though, to compare a battery that's been charged by electricity from a natural-gas-fired power plant with one that's been charged using nuclear power. Natural gas requires burning, produces CO_2, *and sometimes relies on environmentally problematic fracking to release it from the ground. Nuclear power yields hard-to-store wastes as well as proliferation and fallout risks. There's no clear-cut way to compare those impacts. Focusing only on greenhouse gases, however important, misses much of the picture.*

Manufacturers and marketing agencies exploit the fact that every power source carries its own unique portfolio of side effects to create terms of discussion that best suit their needs. Electric-car makers like to point out, for instance, that their vehicles can be charged from renewables sources, such as solar energy. Even if that were possible to do on a large scale, manufacturing the vast number of photovoltaic cells required would have venomous side effects. Solar cells contain heavy metals, and their manufacturing releases greenhouse gases such as sulfur hexafluoride, which has a global warming potential 23,000 times higher than CO_2, *according to the Intergovernmental Panel on Climate Change (IPCC, 2014). What's more, fossil fuels are burned in the extraction of the raw materials needed to make solar cells and wind turbines and also in their fabrication, assembly, maintenance, redundant backup power plants, and decommissioning. Electric-car proponents eagerly embrace renewable energy as a scheme to power their machines, but conveniently ignore the associated environmental repercussions.*

Finally, most electric-car assessments analyze only the charging that occurs during the car's life. This is an important factor, indeed. But a more rigorous analysis would consider the environmental impacts over the vehicle's entire life cycle, from its construction through its operation and on to its eventual retirement at the junkyard.

One study attempted to paint a complete picture. Overseen by the National Academy of Sciences in 2010 and *co-authored by two dozen of the United States' leading scientists, is perhaps the most comprehensive account of electric-car impacts to date. Its findings are sobering.*

It's worth noting that this investigation was commissioned by the U.S. Congress and therefore funded entirely with public, not corporate, money. As with many earlier studies, it found that operating an electric car was less damaging than refueling a gasoline-powered one. It isn't that simple, however, according to Maureen Cropper, the report committee's vice chair and a professor of economics at the University of Maryland. "Whether we are talking about a conventional gasoline-powered automobile, an electric vehicle, or a hybrid—most of the damages are actually coming from stages other than just the driving of the vehicle," she points out (Cropper, 2013).

Part of the impact arises from manufacturing. Because battery packs are heavy (the battery accounts for more than a third of the weight of the Tesla Roadster, for example) ("Tesla Roadster," n.d.), manufacturers work to lighten the rest of the vehicle. As a result, electric cars contain many components made of lightweight materials that are energy intensive to produce and process—aluminum and carbon-composites in particular. Electric motors and batteries add to the energy intensity of electric-car manufacture.

Additionally, the magnets in the motors of some electric vehicles contain rare earth metals. Curiously, these metals are not as rare as their name might suggest. They are, however, sprinkled thinly across the globe, making their extraction uneconomic in most places. In a study released last year (Chandler, 2012), a group of MIT researchers calculated that global mining of two rare earth metals, neodymium and dysprosium, would need to increase 700 percent and 2600 percent, respectively, over the next 25 years to keep pace with various green-tech plans. Complicating matters is the fact that China, the world's leading producer of rare earths, has been attempting to restrict its exports of late. Substitute strategies exist, but deploying them introduces tradeoffs in efficiency or cost.

The materials used in batteries are no less burdensome to the environment, the MIT study noted. Compounds such as lithium, copper and nickel must be coaxed from the earth and processed in ways that demand energy and can release toxic wastes. And in regions with poor regulations, mineral extraction can extend risks beyond just *the workers directly involved. Surrounding communities may be exposed to toxic substances through air and groundwater contamination.*

At the end of their useful lives, batteries can also pose a problem. If recycled properly, the compounds are rather benign—though nothing you'd want to spread across a bagel. But handled improperly, disposed batteries can release toxic chemicals. Such factors are difficult to measure, though, which is why they are often left out of studies on electric-car impacts.

The National Academies' assessment didn't ignore those difficult-to-measure realities. It drew together the effects of vehicle construction, fuel extraction, refining, emissions, and other factors. In a stomach punch to electric-car advocates, it concluded that the vehicles' lifetime health and environmental damages (excluding long-term climatic effects) are actually greater than those of gasoline-powered cars. Indeed, the study found that an electric car is likely worse than a car fueled exclusively by gasoline derived from Canadian tar-sands (National Research Council, 2010).

As for greenhouse-gas emissions and their influence on future climate, the researchers didn't ignore those either. The investigators, like many others who have probed this issue, found that electric vehicles generally produce fewer of these emissions than their gasoline- or diesel-fueled counterparts—but only marginally so when full life-cycle effects are accounted for. The lifetime difference in greenhouse-gas emissions between vehicles powered by batteries and those powered by low-sulfur diesel, for example, was hardly discernible (National Research Council, 2010).

The National Academy study stood out for its comprehensiveness, but it's not the only one to make such grim assessments.

A Norwegian study (Hawkins et al., 2013) published in the Journal of Industrial Ecology compared life-cycle impacts of electric vehicles. The researchers studied effects on acid rain, airborne particulates, water pollution, smog, human toxicity, as well as depletion of fossil fuel and mineral sources. According to co-author Anders Stromman, "electric vehicles consistently perform worse or on par with modern internal combustion engine vehicles, despite virtually zero direct emissions during operation." (Electric cars 'pose environmental threat', 2012)

Last year the National Science Foundation funded investigators from the University of Tennessee who studied five vehicle types in 34 Chinese cities and came to a similar conclusion (Heins, 2012). These researchers focused on health impacts from emissions and particulate matter such as airborne acids, organic chemicals, metals, and dust particles. For a conventional vehicle, these are worst in urban areas, whereas the emissions associated with electric vehicles are concentrated in the less populated regions surrounding China's mostly coal-fired power stations. Even when this difference of exposure was taken into account, however, the total negative health impacts of electric vehicles in China exceeded those of conventional vehicles.

North American power station emissions also largely occur outside of urban areas, as do the damaging consequences of nuclear- and fossil-fuel extraction. And that leads to some critical questions. Do electric cars simply move pollution from upper-middle-class communities in Beverly Hills and Virginia Beach to poor communities in the backwaters of West Virginia and the nation's industrial exurbs? Are electric cars a slight of hand that allows those who are already comfortable to have peace of mind at the expense of intensifying asthma, heart problems, and radiation risks among the poor and politically disconnected?

The hope, of course, is that electric-car technology and power grids will improve and become cleaner over time. Modern electric-car technology is still quite young, so it should get much better. But don't expect batteries, solar cells, and other clean-energy technologies to ride a Moore's Law–like curve of exponential development. Rather, they'll experience asymptotic growth toward some ultimate efficiency ceiling. When the National Academy's researchers projected technology advancements and improvement to the U.S. electrical grid out to 2030, they still found no benefit to driving an electric vehicle.

If those estimates are correct, the sorcery surrounding electric cars stands to worsen public health and the environment rather than the intended opposite. But even if the researchers are wrong, there is a more fundamental illusion at work on the electric-car stage.

All of the aforementioned studies compare electric vehicles to gas-powered ones. In doing so, their findings draw attention away from the broad array of transportation *options available—including living in urban areas and using mass transit.*

No doubt, gasoline- and diesel-fueled cars are expensive and dirty. Road accidents kill tens of thousands of people annually in the United States alone and injure countless more. Using them as a standard against which to judge another technology is a remarkably low bar. Even if electric cars someday pass over that bar, how will they stack up against other alternatives?

For instance, if policymakers wish to reduce urban smog, they might note that the vehicle pollution follows the Pareto principle, or 80-20 rule. Some 80 percent of tail-pipe pollutants flow from just 20 percent of vehicles on the road—those experiencing incomplete combustion. By engineering and installing remote monitoring stations, communities could identify those cars and force them into the shop. That would be far less expensive and more effective than subsidizing a fleet of electric cars.

If legislators truly wish to reduce fossil-fuel dependence, they could prioritize the transition to walkable and bikeable neighborhoods. That won't be easy everywhere—even less so where the focus is on electric cars. The National Academies points to better land-use planning to reduce suburban sprawl and most importantly fuel taxes to reduce petroleum dependence. Following that prescription would solve many problems that the proliferation of electric cars could not begin to address—automotive injuries, deaths and the frustrations of being stuck in traffic among them.

Upon closer consideration, moving from petroleum-fueled vehicles to electric cars starts to appear tantamount to shifting from one brand of cigarettes to another. We wouldn't expect doctors to endorse such a thing. Should environmentally minded people really revere electric cars? Perhaps we should look beyond the shiny gadgets now being offered and revisit some less sexy but potent options—smog reduction, bike lanes, energy taxes, and land-use changes to start. Let's not be seduced by high-tech illusions.

4.2 Analysis of a material semiotic discordance

In publishing this case manuscript, I intended to discover through practice how an analysis that identifies a semiotic and material divide might be drafted and how, specifically, such an analysis be structured and contextualized. I also sought to incorporate potential roles of non-knowledge in the public understanding of electric vehicle development and use. I also intended to assess whether this mode of analysis showed promise to engage professional and lay audiences, the outcome of which will be covered in Section 4.3.

To begin, it was not the goal of the manuscript to evaluate the accuracy of the data within particular studies presented, nor did this work strive to demonstrate that supporters of the electric car were outside some mainstream consensus. Indeed, many electric vehicle researchers do claim that electric cars will produce environmental and economic benefits. Rather, I employed these works as data points in themselves that are worthy of comparison and exploration. I endeavored to expose the hidden assumptions that proponents of electric cars have made, the transportation options they leave out of their analysis, and why. I specifically outlined how research on electric vehicles was structured around just one ecosystem impact measure, nominal carbon dioxide emissions, which was introduced in Chapter 2 as being an example ignorance through aperture. We can see in the case of electric vehicle analysis how a narrow focus on a carbon emissions might consolidate discourse and capital flows into highly directional streams, which can in turn draw attention away from other scales of assessment. For instance, it is perhaps not surprising that researchers at the Electric Power Research Institute would appraise the cleanliness of an electric car differently than do the scientists at the National Academies. The researchers at EPRI studied the electric car's fuel cycle; those at the National Academies looked instead at public health impacts of the electric car's entire life cycle, including vehicle manufacturing. This case manuscript essentially argued that the answers we get depend on the questions we develop in the first place. It formed a critique not of nominal findings of electric vehicle research, but of the way these very questions are asked.

This analysis in effect exposes a type of shallow-depth-of-field ignorance, an ignorance that relies on one layer of effects to speak for the whole. For instance, the measurement of a single practice, such as refueling an electric car, versus a deeper consideration of that single process as one of many – a car that is refueled but also relies on asphalt for a driving surface, bitumen (and therefore petroleum exploration), which requires expertise, which requires universities, which requires cafeterias, and so on. An implication here, and one that in retrospect perhaps should have been made more explicit, was the idea that when our questions deepen the depth of field enough, we may pass a threshold of perceived effects that can represent a tipping point of cumulative effects, which provide a platform for asking another round of much different questions.

To explore a deeper depth of field in this case, this manuscript attends to the larger transportation context. Even if electric cars gain in popularity, will we have invested billions of dollars to maintain an otherwise unsustainable transportation infrastructure (see also McGee, 2017)? I proposed that perhaps the global fascination with electric vehicles has diverted our attention from other initiatives. A reminder of this came during the rush to extend electric-car subsidies, when the U.S. Congress largely gutted a highly successful Safe Routes to School program that was upgrading basic infrastructure for students and educators to walk or bike to school. Might the fact that schools hold bake sales to finance bike racks while car companies bathe in billions of public funds, be seen an important valuation of cleaner transportation, or an inglorious national embarrassment (Zehner, 2012)?

Drawing upon Chapter 2, we can see how in this case narrow aperture, low depth of field carbon emissions can come to be addressed through low aperture and shallow market driven electric vehicle solutions, which are congruent with capital interests. And in turn, we uncover an instance of ignorance becoming a strategic asset. I also unexpectedly discovered what might obvious in retrospect; when assessing depth of field, one never knows how far to stand back. I came up to the limits with this journal's editors. I attempted to incorporate the context of expanding human presence more broadly, but the frame was resisted by the editors of the journal, who were ultimately successful in removing any such contextual reference in its entirety. We might think that these larger concerns are unfair or irrelevant. In a world of eight billion people living in increasingly precarious times, might these be the tough questions that matter? What purposes do our solutions serve in constructively avoiding broader questions, which we do not care to discuss? This editorial decision for contextualizing environmental concerns cannot be addressed in this work might be of interest for further inquiry (see also Ehrlich & Ehrlich, 2013; Shragg, 2015; Weld, 2012).

4.3 Reception and future opportunities

The response to the article came immediately as the issue landed on the desks of hundreds of thousands of engineers around the world. According to three social media companies, the online sharing of this article on their respective platforms exceeded that of all other articles ever published by the journal, combined. The journal received numerous letters, protests, online jeers, and requests to withdraw or refute the article. A member of the Institute of Electronics and Electrical Engineers claimed that the journal's editor put her job on the line to publish the piece and indeed took on a personal toll herself after its release. Given my experience, I would not doubt it. A *USA Today* article written about the paper elicited so many online death threats to myself that the comments section had to be removed. At the same time, National Public Radio planned a short segment with me but kept me on air three times as long as planned due to interest in the topic. The paper went on to win two awards and was named the top trade article of the year by the Tabbies, whose judges felt the paper went " beyond the traditional reporting style to engage readers." As much as I would like to take credit for all of this, it is more likely that the overwhelming reception to the paper was not a result of any writing talent of mine. Rather, I suspect it is largely due to the case that such little writing of this kind exists, indicating that there is great interest for this sort of social scientific analysis among engineering professionals and technology enthusiasts.

As a final note, and related to this observation about a dearth of such writing, subsequent published critics of this paper were unfortunately largely unable to engage the argument, which was intended to be about how quantification of electric vehicle measures work, how carbon mobilizes support for profitable priorities that presume to reduce CO_2, comparisons/benchmarks used, as well as the politics and stakes involved with how and who formulates electric vehicle questions. Instead, respondents chose to push back against some of the studies introduced in the paper by citing contradictory studies with differing facts, missing completely the argument in the paper. The lack of engagement becomes a potential lesson in itself, an opportunity to think about how such arguments are presented but also attend to how engineers in the field may feel that by mobilizing different facts, they can let the "better" facts speak for themselves. I presented wider-scope claims in the hopes of provoking a critique of others' questions but these were taken, understandably in retrospect, to be the premise of the argument itself. This would be something to improve upon in future writing. It may also be complicated by a general unfamiliarity or reluctance among many readers to engage in a social scientific critique about the practices of developing scientific knowledge. In any case, these represent opportunities for better engagement with readers in the future.

Chapter 5: Technological zombie

This chapter employs a zombie metaphor to explore an apparent incongruence between material and semiotic characteristics of the idea of a hydrogen economy by drawing upon theoretical frames that occasionally rise to the surface. Originally published as a book chapter (Zehner, 2012) and updated here, it is the second of four chapters presented as case manuscripts. The analysis is coordinated around the general questions introduced in Chapter 1 inquiring about the nature of material semiotic discordance and what it looks like when it occurs. More specifically, in what ways did symbols of the hydrogen dream become involved with action and material effects within the technological episteme? Did symbolic elements between various actors align, did they remain separate, or did some other organization of semiotic interests manifest? When the discordance, or gap, between the symbolic and the material became too great to sustain, what was the semiotic fallout for the hydrogen dream?

5.1 The life, death, and afterlife of the hydrogen economy

By early 2010 the hydrogen economy might have seemed dead to any casual observer. The financial foundations upon which the hydrogen dream stood had been reduced to a shadow. Numerous governments had slashed, yanked, and all but completely eliminated hydrogen funding. Corporations that hastily filled their pockets bringing hydrogen fuel cells to market eventually witnessed their balance sheets tumbling just as quickly. Finally, after the crash of the hydrogen economy, credit crises and financial upheavals swept away what was left behind. But soon after the fall, something curious occurred.

The New York Times dedicated a full-spread feature to the hydrogen economy and CBS News claimed GM's new hydrogen fuel-cell car was "a terrific drive with almost no environmental impact" (Edgerton, 2010). More recently, California began constructing new hydrogen fueling stations along its touted hydrogen highway. Even though the firms, infrastructure, and funding for the hydrogen economy had collapsed a decade earlier, the dream staggered on – a technological zombie.

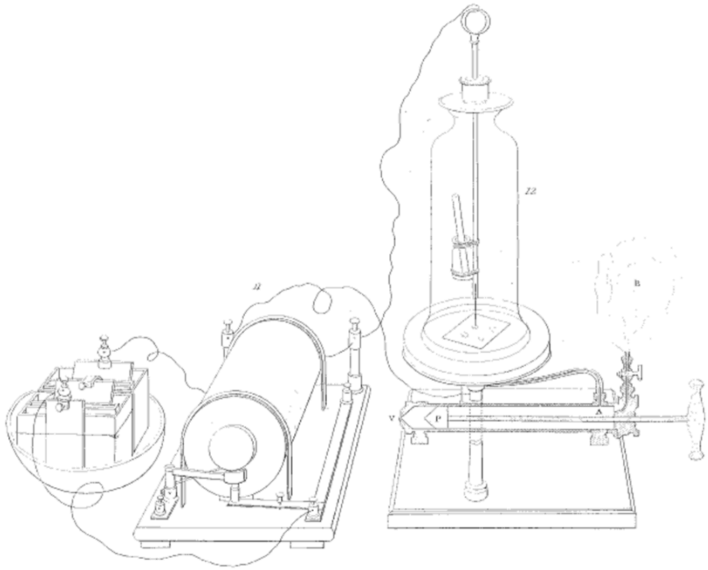
Characterizing hydrogen as a zombie technology might seem a bit harsh for those enchanted by the idea of a hydrogen economy, but in fact it has been called much worse by others – a pipedream, a hoax, or even a conspiracy (Lauro & Embry, 2008; Vaitheeswaran, 2004; Zubrin, 2007). Nevertheless, these hasher concepts are too blunt to carve an intricate appreciation for the rise, fall, and resurrection of the hydrogen dream. A more nuanced rendering offers a peek into how diverse groups can coalesce around a technological ideal to offer it not only a life it would never have achieved otherwise but an enigmatic afterlife as well.

5.2 Alignment of interests

The idea of a hydrogen economy is based on two central components, hydrogen (the gas) and fuel cells (the contraptions that combine hydrogen and oxygen to create electricity). It is important to correct the common misconception that hydrogen is an energy resource. Hydrogen is simply a carrier mechanism, like electricity, which energy firms must produce. Unlike sunlight, tides, wind, and fossil fuels, hydrogen gas does not exist freely on earth in any significant quantity. Processors must forcibly separate hydrogen from other molecules and then tightly contain the gas before distributing it for use. They most commonly derive hydrogen from natural gas, through steam hydrocarbon reforming, or less frequently from water, through electrolysis. Both processes are energy intensive; it always takes more energy to create hydrogen than can be retrieved from it later on. Hydrogen firms presumably won't be able to change this restriction without first changing the first law of thermodynamics and the law of conservation of energy.

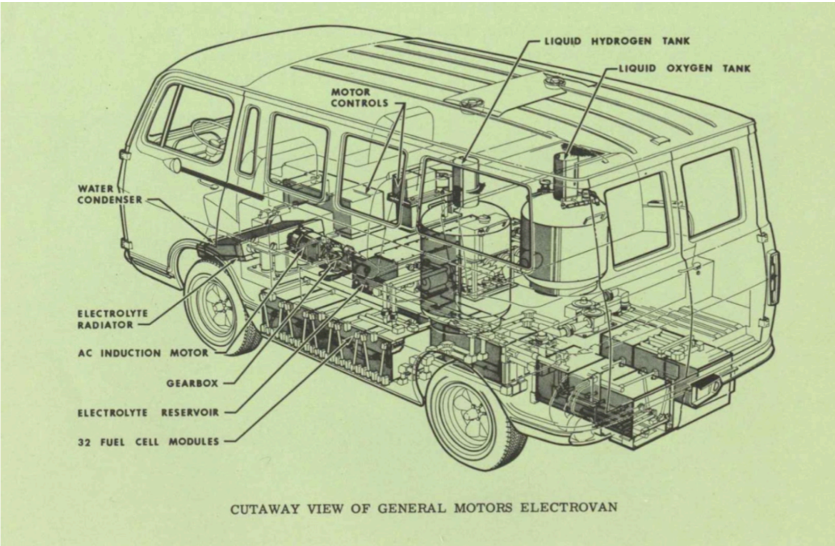
Historians generally credit Sir William Grove for devising the first fuel cell around 1840 although it was another 50 years before chemists Ludwig Mond and Charles Langer made them practical (Morus, 2004). The internal combustion engine revolution overshadowed early fuel cell research. However, proponents slowly coaxed the technology along; General Motors introduced a hydrogen van concept vehicle in 1966 and eventually NASA and General Electric unveiled the first modern platinum fuel cell for the Gemini Space project. In the 1970s the U.S. government, scrambling to respond to oil embargos, began to work more closely with industry to advance fuel cell research and in the 1980s other car manufacturers joined in.

Figure 5.1: An illustration of Sir William Grove's fuel cell, which he called a gas voltaic battery, published by the Royal Society of London in 1852 (Grove, 1852).



By the early 2000s, almost every automotive company had initiated a fuel cell program. At the 2006 Los Angeles Autoshow, California Governor Arnold Schwarzenegger stood on a stage to anoint fuel cell vehicles "the cars of the future" (Schwarzenegger, 2006). Shortly after, BMW CEO Dr. Michael Ganal took to the podium to declare "The day will come when we will generate hydrogen out of regenerative energies, and the day will come when we will power our cars by hydrogen. This means no exploitation of natural resources anymore; this means no pollution anymore. We know there is a far way to go, and the new BMW Hydrogen 7 is a big step towards the future" (Ganal, 2006).

Figure 5.2: General Motors teamed up with Union Carbide Corporation to create an 'Electrovan,' concept vehicle, which ran on tanks of hydrogen, oxygen, and potassium hydroxide. Citing potential "operating hazards," General Motors created a special test track for the vehicle, set away from its design and engineering buildings. Any volunteers? (General Motors, 1966).



BMW's Hydrogen 7, along with its numerous American counterparts, such as the Chevrolet Equinox and Jeep Treo, might never have been built if not for one of George W. Bush's earliest projects, the National Energy Policy Development Group, which was headed by Dick Cheney and charged with identifying future energy markets. The group immediately locked in on hydrogen. It identified the elemental gas as the "future" and dubiously referring to hydrogen as an "energy source" that produced but one "by-product," water (National Energy Policy Development Group, 2001). They mentioned few details about how hydrogen might be produced, beyond the claim that it could be created with renewable resources. Most shockingly, the report explicitly considered nuclear power and fossil fuels to be "renewable energy sources" (National Energy Policy Development Group, 2001). This remarkably generous definition proved quite useful – especially when it came to enrolling supporters. The commission invited CEOs of British Petroleum, DaimlerChrysler, Ford, Exxon, Entergy Nuclear, the National Energy Technology Laboratory, Texaco, Quantum

Technologies, and the World Resources Institute to help draft the boilerplate language describing hydrogen that would be adhered to by all constituents, and subsequently copied-and-pasted into ad campaigns, PR initiatives, and annual reports more or less word-for-word. In 2002, The United States Department of Energy (DOE) formalized the coordination with two reports. One of the reports concluded that the government should treat dissenting views regarding hydrogen as "perceptions based on misinformation," which should be "corrected" (U.S. Department of Energy, 2002). A subsequent report claimed, "The government role should be to utilize public resources to assist industry in implementing this massive transition and in educating the public about fuel cell vehicles' safety, reliability, cost and performance" (U.S. Department of Energy, 2003). The DOE determined that the public reeducation campaigns were to start as early as grade school. The European Commission adopted corresponding language and education campaigns following the DOE script, which energy multinationals presumably transferred overseas from Washington.

It may not be immediately evident why traditional energy giants were so keen on hydrogen. But it may start to make sense when we consider the enormous quantity of energy required to pry hydrogen atoms from their molecular resting places. Hydrogen generation processes can easily use more fossil fuel than simply deploying natural gas and coal in their traditional dirty manners. Coordinators of California's "Hydrogen Highway" even admitted that their vehicles led to more particulate matter and greenhouse gas emissions than gasoline-powered vehicles on a well-to-wheel basis (California Hydrogen Highway Network, 2007). Still, promoting hydrogen as a clean fuel that energy companies could create using "renewable energy sources" promised to offer particularly valuable environmental cover for dirty fossil fuel operations. If only mainstream environmental organizations could be brought on board; but how?

Throughout the world, numerous geothermal sources, wind farms, and industrial processes emit excess energy that producers can capture, convert, and store in the form of hydrogen, at some cost. These overflows were, and are still today, far too rare and inadequate to produce large sums of hydrogen – certainly not enough to run an economy of appreciable size. But the concept was nevertheless alluring, even if it was far-fetched. This ambiguity didn't stop environmental organizations from joining hands with fossil fuel giants to celebrate the hydrogen dream together (Hultman, 2009). So long as the public associated hydrogen with windmills, it didn't really matter how much production occurred behind the scenes using natural gas or coal reformation. The troupe was complete, almost.

Automotive companies danced with fuel cells in the public spotlight; the U.S. and European governments got to task on re-educating the public; and fossil fuel companies manned the gates of the whole operation. Yet, another industry waged its bets less conspicuously. In fact, insiders sometimes characterize it as the scowling director of the hydrogen ballet: the nuclear power industry. The nuclear industry's inclinations toward hydrogen were presumably analogous to those of the fossil fuel industries', save for one small twist. Given the limitations of solar and wind energy systems, the nuclear industry was positioned to present itself as the only "clean" solution for creating hydrogen on a *large scale*.

Many years before BMW unveiled the Hydrogen 7 at the Los Angeles Autoshow, the nuclear industry lobbied Congress in an effort to direct large segments of the Department of Energy's research funds toward a Next Generation Nuclear Plant (NGNP). Like any nuclear power plant, the NGNP would generate electricity. It would also produce hydrogen. The nuclear industry had a persuasive proponent, Congressman Darrell Issa, a powerful energy productivist and then Congress' wealthiest member, worth about $250 million according to The Center for Responsive Politics (Levinthal, 2009). During a 2006 congressional hearing before the Subcommittee on Energy and Resources, Representative Issa could not have been more explicit about the link between the nuclear industry and the hydrogen dream. He stated that the Next Generation Nuclear Plant was "a key component in the Administration's plans to develop the 'hydrogen economy' because an associated purpose of the advanced demonstration plant is to produce hydrogen on a large scale" (U.S. House of Representatives, 2006). If anyone had been uncertain of the nuclear industry's interest in the hydrogen game, Issa put those concerns to rest. The nuclear industry was in. A new nuclear power plant had not been built in the U.S. for decades. Hydrogen provided a convenient opportunity to reposition nuclear power as an environmentally progressive undertaking for the nation to pursue – one that would eventually end up costing taxpayers dearly.

But beyond the nuclear industry, California politicians, car companies, and fossil fuel giants, there were plenty of others excited to get in on the action. Academic researchers, scientists, environmentalists, journalists, and of course the fuel cell manufactures themselves all had something to gain from the hydrogen dream. Without the unorganized gravitation of their interests around the shared and powerful vision of this tiny molecule, the hydrogen dream might never have been. Had the various story lines surrounding hydrogen not coalesced to fertilize this progression from option to requirement, the ultimate perceived necessity for a hydrogen future may never have gained legitimacy in the first place. It is important to note that this particular alignment of interests looks a lot like the interests acting to stabilize the movement behind solar cells, wind turbines, and biofuels. However, unlike the strong bonds propping up the larger dream of an alternative energy future, the ties tightened around the hydrogen dream eventually began to loosen.

5.3 The Undoing of a spectacle

A growing minority of energy analysts started discounting hydrogen as nothing but hype. These included Joseph Romm, a former Department of Energy director and Mark Jaccard whose work with Intergovernmental Panel on Climate Change was about to be recognized with a Nobel Peace Prize. Others, including Lockheed Martin engineer and technophile Robert Zubrin, who thought the colonization of mars was a real possibility, characterized hydrogen as a far-flung hoax. These and other critics began to argue that plans to use hydrogen on a scale even approaching the size necessary to displace fossil fuel consumption would have required not just a couple of large breakthroughs, but rather numerous breakthroughs that were each monumental in their own right. Their attacks came from multiple fronts, covering hydrogen production and transport as well as its eventual use in fuel cells.

Once hydrogen is created, critics maintained, the challenges to employ it as a fuel multiply. First, hydrogen must be contained, either as a supercooled liquid below negative-253 °C or as compressed gas. Both of these processes were energy intensive. High-pressure pumps consumed up about 20% of the energy in the hydrogen for compression, while liquification wasted 40% of the embodied energy, according to Zubrin (2007). Maintaining hydrogen in its liquid form required specially insulated vessels and massive refrigeration power. For instance, Governor Schwarzenegger's car of the future, the BMW Hydrogen 7, stored cryogenic liquid hydrogen in its tank. While parked, the supercooled liquid would warm up inside the car's 30-gallon tank. Internal sensors allowed the expanding explosive gases to build to a maximum pressure head of 5.5 bar, at which time (assuming everything worked correctly) the hydrogen would overflow through a pressure valve, combine with oxygen, and drip onto the ground as water. As long as the car was parked, the process would continue until the tank was empty. Reporter Matthew Phenix quipped in a *WIRED* magazine report that the derisory Hydrogen 7 was "saving the world, one PR stunt at a time" (Phenix, 2007). Not a particularly glowing endorsement from perhaps the most techno-friendly news source in the nation.

In other concept vehicles, on-board supercoolers held hydrogen in its liquid form, but these units had to be powered 24-7. Other storage options involved blocks of solid metal hydride materials – essentially giant heavy sponges capable of soaking up hydrogen – but even after years of development such schemes proved clumsy. The most promising hydrogen concept vehicles stored their hydrogen as a compressed gas rather than as a liquid, but the tanks were large and ponderously heavy unless crafted from expensive carbon fiber materials, which critics deemed were more apt to explode in a crash (Satyapal et al., 2007). Even though other researchers believed these tanks would be as safe as natural gas or gasoline storage, convincing the public would be the larger hurdle. Perhaps drivers might have felt hesitant to zoom down the freeway atop pressurized tanks of hot-tempered gas – especially if that gas had an atomic bomb named after it or brought to mind an exploding Zeppelin. Critics also attacked the proposed hydrogen transportation and filling-station infrastructure. There's the obvious chicken-and-egg problem; why would car companies produce hydrogen vehicles without hydrogen filling stations and why spend billions for an infrastructure without an existing market of hydrogen-vehicle owners waiting to fill up? True, legislative tools could have spurred such construction, as was begun in California, but to develop an infrastructure the size of the gasoline network would have cost half a trillion dollars in the United States alone according to a Department of Energy chief (Romm, 2004).

Even with a small infrastructure, dissenters pointed out that distributing the gas to filling stations by tanker truck would have been difficult given hydrogen's low energy content per unit of volume compared with other fuels. A tanker truck can carry enough gasoline for 800 cars, but can only hold enough hydrogen for 80 (Jaccard, 2005). This would lead to a lot of back-and-fourth trips, consuming enough diesel to offset 11% of the hydrogen's energy after just a 150-mile jaunt, according to one critic (Wise, 2006). Distributors could have shortened the trips by building pipelines but hydrogen distribution requires specialized pipeline technologies to prevent leakage; hydrogen can seep right through the walls of a solid pipe, a serious consideration given the large surface area of a distribution pipeline (Somerday & San Marchi, 2008).

Reforming natural gas into hydrogen right at filling stations could have bypassed some distribution concerns, but hydrogen detractors argued that the nation's drivers would be better off simply pumping natural gas directly into their vehicles rather than going through the trouble of reforming it into hydrogen, which would contain less energy, yield the same greenhouse gasses, occupy three times the volume, and limit use to fuel-cell vehicles that were incredibly expensive.

Nevertheless, hydrogen proponents pointed to a cleaner way to secure hydrogen: electrolysis, a process wherein electricity separates water into hydrogen and oxygen. Environmental proponents envisioned wind turbines and solar panels would power the electrolysis. Meanwhile, fossil fuel and nuclear industry executives knew they didn't have to worry about such alternatives taking over their hydrogen production activities any time soon. In 1994, the State of California erected a solar-powered hydrogen station called "Sunline" outside of Palm Springs, but it took the entire station 10 hours of solar electrolysis to produce just 1kg of hydrogen, the energy equivalent of about one gallon of gasoline. Hooked to the grid and drawing power from nearby wind turbines, the station could have theoretically produced up to 16kg of hydrogen per day, "assuming optimal season conditions," according to Sunline's own calculations (California Hydrogen Highway Network, 2005).

Another concern was eclipsing the difficulties of creating the hydrogen fuel itself. Critics narrowed in on the high cost and durability of fuel cells, the electro-chemical devices that could combine hydrogen and oxygen to create usable electricity for cars, buildings, laptops, and other devices. There was little argument that when coupled with an electric motor in a vehicle, fuel cells were more efficient than internal combustion engines. However, critics pointed out that fuel cell designs only had an operational life of about 30,000 miles and therefore had to be replaced more frequently than a car's brake pads – and the fuel cells weren't cheap (Difiglio & Gielen, 2007). This was largely due to the high cost of platinum, which was utilized in proton exchange membrane fuel cells as a catalyst in layers just a few atoms thick. Even at these reduced concentrations, economists warned that large-scale fuel cell production could spark platinum price bubbles, tilting the overall scheme into an uphill economic challenge unless manufacturers could identify a cheap platinum substitute.

In short, critics argued that automotive fuel cell experience had proven the gadgets to be extraordinarily expensive, finicky in bad weather, short-lived, and prone to molecular clogging, which dramatically reduced their efficiency. Joseph Romm, former director of the US Department of Energy's Office of Energy Efficiency and Renewable Energy observed, "If the actions of Saddam Hussein and Osama Bin Laden and record levels of oil imports couldn't induce lawmakers, automakers, and the general public to embrace existing vehicle energy efficiency technologies that will actually pay for themselves in fuel savings, I cannot imagine what fearful events must happen before the nation will be motivated to embrace hydrogen fuel cell vehicles, which will cost much more to buy, cost much more to fuel, and require massive government subsidies to pay for the infrastructure" (Romm, 2004).

Hydrogen's future wavered.

5.4 Expectation and materiality

It began just like any other bubble. By the early 2000s, the costs of commercially-viable fuel cells had triumphantly dropped from the tens of millions of dollars per unit in the 1960s to below $100,000. Stocks of fuel cell and hydrogen-related component manufacturers such as Ballard Power Systems and Millennium Cell sprang to all-time highs. And in 2006, *Popular Mechanics* magazine predicted that fuel cells could cost as little as $36,000 if mass produced (Wise, 2006). That year, a company called Smart Fuel Cell hit the stock market commanding an impressive market capitalization trading at $150 per share. But the banana peel was already laid out.

Platinum prices were rising. In the early years of the century, spot prices for platinum doubled. Even as pundits proclaimed that the rare metal was overpriced, prices doubled again by 2008. It wasn't just platinum prices that were making investors jittery; traders noticed that even though fuel cell firms were not burning oil, they were quickly burning through cash. "The bread-and-butter profits we need to see are years away. It's not even a niche market yet," observed John Webster, coauthor of a Pricewaterhouse-Coopers investigative study on fuel cells (Webster, DeLucchi, & Nimmons, 2003). Esteemed industry analyst, David Redstone, pointed out that even though Ballard Power Systems had "a great public relations machine," and politicians were "interested in fuel cells," the industry as a whole had overpromised. "There is not a stream of commercial revenue. There are not products. Overpromising and underperforming leads to investor disappointment," claimed Redstone (Snow, 2003; Dobosz, 2002). Investors eventually fled.

A year after Smart Fuel Cell's issue, the stock had dropped from $150 to $50 and by 2008 it was trading below $15. Ballard Power Systems, which had been trading at over $100 per share, plummeted to $4. Investors slashed the market capitalization of Millennium Cell in half by 2002, then again by 2004, then again by 2006 – the same shares that attracted investors at $25 in 2000 were having a difficult time finding support at the 5-cent level in 2009. By 2010, keepsake investors could buy 25 shares for less than a penny.

The smart money left and so left the politicians. Posthaste. Originally, Schwarzenegger had forecasted a "Hydrogen Highway" with 150-200 filling stations by 2010 but by 2009 the state had completed only a couple dozen and the project had stalled even before Schwarzenegger left office in January 2011. Governor Schwarzenegger dropped the hydrogen dream as quickly as he had picked it up. So did President Bush. After becoming a central feature to George W. Bush's energy plan in 2003, he didn't even utter the word "hydrogen" during his State of the Union address in 2007 or any time thereafter. Subsequently, he quietly pulled funding for a FutureGen coal-to-hydrogen production facility, which proponents considered a key element in realizing their dream (Biello, 2008). During his first months in office, president Obama finished the job by proposing to eliminate the remaining $100 million of funding from the federal government's hydrogen fuel cell venture with carmakers (Office of the Chief Financial Officer, 2009). At the announcement, energy secretary Steven Chu said "We asked ourselves, 'Is it likely in the next 10 or 15, 20 years that we will convert to a hydrogen car economy?' The answer, we felt, was 'No.'" (Biello, 2008). Chu renamed the hydrogen fuel cell group and recommended reorienting remaining fuel cell research away from vehicles and toward a few low-prestige applications such as building power backup and battery replacement. Betrayed, broke, and finished off – the hydrogen economy was dead. But it was still moving.

5.5 Technology as story

After yielding audience to the hydrogen skeptics, it is perhaps difficult to imagine the "hydrogen economy" as anything more than a smokescreen designed so political and corporate elites might dazzle the electorate as they shuffled energy subsidies behind their backs. While there may indeed be a good bit of shuffling going on in Washington, the lesson behind hydrogen, as with many other energy technologies, is far more nuanced than the existing assemblage of pyrotechnic literature on the subject might indicate.

Figure 5.3: A Google Trends chart representing search interest for the term "hydrogen economy" relative to the highest point of interest, indicated by a value of 100 on the y-axis. No Google Trends data are available for this term prior to 2004. (Image courtesy of Google Trends, 2018)

The hopes and dreams for a hydrogen economy declined after a peak of public interest that occurred somewhere around the mid 2000s according to my research. Early on, some investors determined that automotive fuel cells were nothing more than glorified science-fair experiments, hardly a reasonable basis for alleviating smog, CO_2 emissions, conflicts, and costs associated with the nation's dependence on fossil fuels. Chu, the Nobel-Prize-winning energy secretary, would eventually prove similarly unimpressed (Biello, 2008). Yet, well established hydrogen promoters continued to promote them to technophile audiences. It wasn't just environmental groups, carmakers, and mainstream energy companies, but also political representatives through many levels of state and federal government, and all the way to the oval office.

Critics claim that we spent billions for nothing. For instance, Zubrin concluded, "the hydrogen economy makes no sense whatsoever. Its fundamental premise is at variance with the most basic laws of physics. The people who have foisted this hoax on the American political class are charlatans, and they have done the nation an immense disservice" (Zubrin, 2007). Hydrogen critics frequently conclude that there existed a hoax that represented the intentional generation of physical ignorance and that the real truth was somehow kept secret. But, the formal and informal coordination between regulators, politicians, public interest groups, environmentalists, and corporations did not present the possibility for an outright conspiracy of the sort plotted by suspense novelists. Only the most tightly controlled organizations can hold a slippery secret in their grasp without it being leaked. Had such a diversity of people been in on a hydrogen ruse, someone would have eventually squealed. Yet, if nobody manufactured a hoax, then how was the effect of a hoax created?

This question becomes even more complex. Even though the hydrogen industry had collapsed, the reversal in fortunes didn't faze the public, scientific, or media enthusiasm surrounding hydrogen in subsequent years. Numerous government and university research budgets and disbursements, which had been pre-planned years prior, were still flowing. The nuclear establishment kept its hydrogen sights on autopilot. Car company PR and advertising departments still found it useful to present their fuel cell concept cars to the public. Journalists were evidently no savvier; the New York Times published a pro-hydrogen feature in 2009, in which it embarrassingly cheered on an industry and its associated product lines that had essentially been bankrupted years previously. The New York Times was not alone. Even though the hydrogen economy had died, its representatives were still busy posing for photo shoots, presenting at environmental conferences, speaking for the automotive industry, booking international trips, and eating at fine restaurants. The industry had even orchestrated a coup d'état in Congress to partially reinstate its funding. The hydrogen economy was not dead, but undead.

How was this possible? Why was the hydrogen dream so remarkably transcendent? Some might claim the hydrogen economy was never really alive to begin with; it surely never existed in any tangible way. Few people had ever seen a fuel cell vehicle, let alone driven one. Perhaps the hydrogen economy was nothing more, and nothing less, than a dream – an remarkably good one. In any case, we can think about the *in situ* ignorance surrounding the effects of hydrogen techniques in actual use, simply because the vehicles and support infrastructure had not been deployed to any appreciable scale. Such ignorance may have allowed people the luxury of imagining a world of abundant energy, a clean utopia where the only pollution would be water vapor, with enough material science mixed in to make the whole affair seem plausible. Various forms of ignorance about material and energy inputs, especially around the manufacture of hydrogen fuel, opened a welcome opportunity for critical environmental inquiry to be displaced by legitimized utopian impulses. In the case of the hydrogen dream, where large scale testing was impossible, demonstrations would suffice - the results of which were constrained through a series of legitimating articulations that were to a large degree market driven.

Since the 1970s environmentalism in America and Europe has often gravitated toward the theme of ecological modernization – the idea that the treadmill of technological progress will solve or at least largely mitigate environmental troubles – that the solution to our energy problems is to produce more energy. Verhees (2012) considers a sort of front-stage and backstage operation of legitimation and promotion. Verhees (2012) identifies a *cultural legitimation cycle*, wherein "proponents perform reframing activities of the technology before audiences of resource controllers outside the view of the wider public," subsequently leading to an *extension phase,* where "they perform the new storyline to recoup wider societal support." These storylines can become enchanting and as a result can coordinate interests around high risk or expensive projects. Morone and Woodhouse (1989) compare the excitement surrounding the Apollo space program to that of postwar nuclear power development. In a parallel strain, Hultman (2009) compares the utopian visions surrounding the hydrogen economy with the ones once envisioned by proponents of nuclear power. "They are similar in that they both invoke the dream of controlling a virtual *perpetuum mobile*, propose an expert/lay knowledge gap, downplay any risks involved, and rely on a public relations campaign to ensure the public's collaboration with companies and politicians," explains Hultman (2009). "The idea that the *level* of energy use is unimportant and not connected to environmental problems is constructed by describing fuel cells as intrinsically clean in themselves and producing only water as exhaust" (Hultman, 2009).

Others might say the hydrogen economy never died. After all, technologies are more than just physical artifacts – the gears, the batteries, the circuit boards. Technologies are a hybrid of intentions, interests, promises, and pretensions. Technologies are stories. If they were not, perhaps they would never catch on. The story of the hydrogen economy likely could not have been formed and fueled by just any single interest group, any single conspirator, or any single hoaxer as it were. As we have witnessed with other energy technologies, the hydrogen dream arose from a complex alignment of interests coalescing to synchronize a future narrative – one that featured selected benefits and additionally benefitted from various forms of non-knowledge about material inputs, side effects, and limitations.

Elected officials, many of whom had worked in the energy sector and were tacitly imbued with its productivist cant, stood to gain both donors and constituents by supporting clean hydrogen. Gas, coal, and nuclear industrial elites knew there was money to be made and valuable cover to be gained by articulating clean hydrogen visions. Academic researchers knew their work would be funded if it was framed as a national priority. Environmentalists could feel good about their work, while gaining public and monetary support by pledging allegiance to the clean fuel of the future. Automotive manufacturers saw opportunities for subsidies, profits, and most of all a clean PR cloak, which they could use to protect themselves from attacks by those who saw their industry as socially and environmentally destructive. And the greater public, primed with the verve of ecological modernization, was willing, perhaps even eager, to be convinced that hydrogen was, in fact, the future of energy.

Chapter 6: Solar cell narratives in context

This chapter is the third of four chapters presented as case manuscripts[7] and presses further to continue the thread started in Chapter 3 comparing the expectations for solar development with published data available leading up to and after the rise in fossil fuel prices and eventual global economic crisis thereafter. First, what were the specific benefits associated with solar cells during the period? And, second, how did these expectations map on to the published material understandings of these technologies at the time? Finally, how does this relationship form the questions we might choose to consider about solar technologies?

6.1 Identifying solar narratives

Throughout the diverse disciplines of business, politics, science, academia, and environmentalism, solar cells stand tall as a valuable technology that most experts agree is worthy of advancement. We find ample support for solar cells voiced by politicians, environmentalists, academics, and even fossil fuel companies. We ordinarily encounter the dissimilar views of these groups bound up in a tangle of conflict, but solar energy forms a smooth ground of commonality where environmentalists, corporations, politicians, and scientists can all agree. The notion of solar energy is flexible enough to allow diverse interest groups to take up solar energy for their own uses: corporations crown themselves with halos of solar cells to cast a green hue on their products, politicians evoke solar cells to garner votes, and scientists recognize solar cells as a promising well of research funding. It is in everyone's best interest to broadcast the advantages of solar energy. And they do. Proponents typically associate the following benefits with solar photovoltaic technology:

- CO_2 Reduction: Even if solar cells are expensive now, they're worth the cost to avoid the more severe dangers of climate change.
- Simplicity: Once installed, solar panels are silent, reliable, and virtually maintenance free.
- Cost: Solar costs are rapidly decreasing.
- Economies of scale: Mass production of solar cells will lead to cheaper panels.

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[7] Original version published in Green Illusions (Zehner, 2012)

- Learning by doing: Experience gained from installing solar systems will lead to further cost reductions.
- Durability: Solar cells last an extremely long time.
- Local energy: Solar cells reduce the need for expensive power lines, transformers, and related transmission infrastructure.

Over the past half century, journalists, authors, politicians, corporations, environmentalists, scientists, and others have eagerly ushered an array of solar devices into the spotlight, reported on their spectacular journeys into space, featured their dedicated entrepreneurs and inventors, celebrated their triumphs over dirty fossil fuels, and dared to envisage a glorious solar future for humanity. As reviewed in Chapter 3, environmental writing during the energy shock from 2003-2008 might have understandably led readers to presume this sunny resource did not present serious limitations. So, it is perhaps not surprising that after the 2008 economic crisis, politicians hastily allocated billions of dollars and euros toward solar technologies in an attempt to motivate capital spending and stimulus through "shovel ready" projects. This chapter compares the perceived attributes of solar cells to their material characteristics measured in two of the largest experience-based deployments of solar technologies available to policy makers at the time of the 2008 crisis and into the subsequent period of stimulus planning – 1) the field deployment of solar technologies in California and 2) solar testing for the Masdar City project which was being planned and built at the time.

6.2 Photovoltaic costs

Historians of technology track solar cells back to 1839 and credit Alexandre-Edmond Becquerel for discovering that certain light-induced chemical reactions produce electrical currents. Charles Fritts installed a solar array on a New York City rooftop in 1884 and in 1940 solid-state diodes emerged to form a foundation for modern silicon solar cells (Perlin, 2013). The first modern solar cells premiered just eighteen years later, aboard the U.S. Navy's Vanguard 1 satellite (Markvart, 2000). Today manufacturers construct solar cells using techniques and materials from the microelectronics industry. They spread layers of p-type silicon and n-type silicon onto substrates. When sunlight hits this silicon sandwich, electricity flows. Newer thin-film technologies employ less of the expensive silicon materials. Researchers have been advancing organic, polymer, nanodot, and many other solar cell technologies.

When I give presentations on renewable energy, the most common questions is, "Why can't we get our act together and invest in solar cells on a scale that could really create an impact?" A goal of this chapter is to consider for a moment if this could be a meaningful question or if there are alternative ones, through contrasting some material observations against the symbolic representations we have covered thus far.

Numerous articles and books contain a statistic reading something like this: Just a fraction of some-part-of-the-planet would provide all of the earth's power if we simply installed solar cells there (see also Capellán-Pérez, De Castro, & Arto, 2017). For instance, before the ramping up of solar subsidies following the 2008 economic crisis, environmentalist Lester Brown, president of the Earth Policy Institute, indicated that it was “widely known within the energy community that there is enough solar energy reaching the earth each hour to power the world economy for one year” (Brown, 2008, p. 252). Even Brown's nemesis, skeptical environmentalist Bjorn Lomborg claimed that “we could produce the entire energy consumption of the world with present-day solar cell technology placed on just 2.6 percent of the Sahara Desert” (Lomborg, 2001, p. 159). Journalists, CEOs, and environmental leaders widely disseminated variations of this statistic by repeating it almost ritualistically in a mantra honoring the monumental promise of solar photovoltaic technologies. The problem with this statistic is not that it is flatly false, I would argue, but that it is somewhat true.

"Somewhat true" might not seem adequate for making public policy decisions, but it has been enough to propel this statistic, shiny teeth and all, into the limelight of government studies, textbooks, official reports, environmental statements, and into the psyches of millions of people. It became an especially powerful rhetorical device despite a notable material caveat. While it is certainly plausible to state that the quantity of solar energy hitting that small part of the desert is equivalent to the amount of energy we consume, it does not necessarily follow that we can harness, store, and use it, an extension many solar promoters explicitly or implicitly assume when they repeat the statistic. Similarly, any physicist can explain how a single twenty-five-cent quarter contains enough energy bound up in its atoms to power the entire earth, but since we have no way of accessing these forces, the quarter remains a humble coin rather than a solution to our energy needs.

To begin, let us consider how much it might have actually cost to build a solar array capable of powering the planet with experience-based data available in the period leading up to the 2008 economic crisis (saying nothing yet about the potential for subsequent cost reductions). By comparing global energy consumption with some of the lowest large-scale photovoltaic cost estimates published, courtesy of solar proponents at the time, we can roughly sketch an estimate. The solar cells would have cost about $59 trillion; the mining, processing, and manufacturing facilities to build them would have cost about $44 trillion; and the batteries to store power for evening use would have cost $20 trillion; bringing the total to about $123 trillion plus about $694 billion per year for maintenance according to an estimate of the most cost-effective large scale deployments at the time (Faiman, Raviv, & Rosenstreich, 2007). If actual installed costs for solar projects in California had been used as a guide, a global solar program would have been estimated to cost roughly $1.4 quadrillion, larger than the global GDP (calculations based on data from Wiser et al., 2006; Harris & Moynahan, 2007).

That said, few solar cell proponents believed that nations ought to have relied exclusively on solar cells. They typically proposed an alternative energy future with an assortment of energy sources - wind, biofuels, tidal and wave power, and others. Still, calculating the total estimate for solar might have brought up some critical questions. Could manufacturing and installing photovoltaic arrays with 2008 technology on any scale have been equally absurd? Did it just not seem as bad to throw away a few billion dollars at a time?

The Earth Policy Institute claimed solar electricity costs were “falling fast due to economies of scale as rising demand drives industry expansion” (Fischlowitz-Roberts, n.d.). The Worldwatch Institute agreed, claiming that “analysts and industry leaders alike expect continued price reductions in the near future through further economies of scale and increased optimization in assembly and installation” (Sawin, 2008). At first glance, this might have seemed to be great news; if solar cell costs were dropping so quickly then it might not have seemed long to planners at the time before it would be possible to clad the planet with them. There was little disagreement among economists that manufacturing ever larger quantities of solar cells resulted in noticeable economies of scale. Although it is not as apparent whether they believe these cost reductions were particularly significant *in situ*. They cited several reasons (Harris & Moynahan, 2007; Galbraith, 2008; Nemet, 2008). First, they warned, it was precarious to assume that the solar industry would realize substantial quantities of scale unless solar cells were to be seen by bankers as cost competitive with other forms of energy production. Up until that time, solar photovoltaic investments had historically been tossed about indiscriminately like a small raft in the larger sea of the general economy. Expensive solar photovoltaic installations gained popularity during periods of high oil costs, but then were often the first line items legislators cut as energy prices softened. For instance, during the oil shock of the 1970s, politicians held up solar cells as a solution, only to toss them aside once the oil price tide subsided.

Second, solar advocates claimed dramatic historical photovoltaic cost reductions since the 1960s, leaving an impression that the chart of solar cell prices was shaped like a sharply downward-tilted arrow, as introduced in the second chapter. But according to the solar industry, prices over recent years had flattened out. Between 2004 and 2009, the installed cost of solar photovoltaic modules actually increased. However, even if solar cells had become cheaper, the drop may not have presumably generated much impact since photovoltaic panels themselves represented less than half the cost of an installed solar system, according to the industry.

6.3 Transmission and timing

Solar cells had long offered benefits in niche applications when they supplanted disposable batteries or other expensive energy supply options. For example, road crews frequently used, and still do use, solar cells in tandem with rechargeable battery packs to power warning lights and monitoring equipment along highways. In remote and poor equatorial regions of the world, tiny amounts of expensive solar energy were seen to generate a sizable impact on families and their communities by providing a viable alternative to candles, disposable batteries, and kerosene lanterns, which were expensive, dirty, unreliable, and dangerous. Could rich nations realize similar transmission-related benefits? Coal power plants require an expensive network of power lines and transformers to deliver their power. Locally produced solar energy may have still required a transformer but it bypassed the long-distance transmission step.

Transmission and timing advantages of solar electricity led the director of the University of California Energy Institute, Severin Borenstein, to find out how large these benefits were in practice. Borenstein's research (2008) suggested that "actual installation of solar PV [photovoltaic] systems in California has not significantly reduced the cost of transmission and distribution infrastructure, and is unlikely to do so in other regions." Why? First, he claimed most transmission infrastructure had already been built, and localized solar-generation effects were not enough to reduce that infrastructure. Even if they had been, the savings would have been small since solar cells alone would not have shrunk the breadth of the distribution network. Furthermore, California and other states had not targeted investments toward easing tensions in transmission-constrained areas. Borenstein took into account the advantageous timing of solar cell output but he ultimately concluded at the time: "The market benefits of installing the current solar PV technology, even after adjusting for its timing and transmission advantages, are calculated to be much smaller than the costs. The difference is so large that including current plausible estimates of the value of reducing greenhouse gases still does not come close to making the net social return on installing solar PV today positive" (Borenstein, 2008). In a world with limited funds, these findings didn't position solar cells well. Still, solar advocates insisted the expensive panels were a necessary investment if nations intended to place their stakes in the future of energy. We would learn more, they argued, by just doing it.

6.4 Learning-by-doing effects

In the 1980s Ford Motor Company executives noticed something peculiar in their sales figures. Customers were requesting cars with transmissions built in their Japanese plant instead of the American one. This puzzled engineers since both the U.S. and Japanese transmission plants built to the same blueprints and same tolerances; the transmissions should have been identical. They weren't. When Ford engineers disassembled and analyzed the transmissions, they discovered that even though the American parts met allowable tolerances, the Japanese parts fell within an even tighter tolerance, resulting in transmissions that ran more smoothly and yielded fewer defects - an effect researchers attribute to the prevalent Japanese philosophy of Kaizen, a model of continuous improvement achieved through hands-on experience with a technology. After World War II, Kaizen grew in popularity, structured largely by U.S. military innovation strategies developed by W. Edwards Deming. The day Ford engineers shipped their blueprints to Japan marked the beginning of this design process, not the end. Historians of technological development point to such learning-by-doing effects when explaining numerous technological success stories. We might expect such effects to benefit the solar photovoltaic industry as well.

Indeed, there are many cases where this kind of learning by doing had aided the solar industry. For instance, the California Solar Initiative solved numerous unforeseen challenges during a multiyear installation of solar systems throughout the state - unexpected and burdensome administration requirements, lengthened application processing periods, extended payment times, interconnection delays, extra warranty expenses, and challenges in metering and monitoring the systems. Taken together, these challenges spurred learning that would not have been possible without the hands-on experience of running a large-scale solar initiative (Harris & Moynahan, 2007). Solar proponents had claimed this kind of learning was bringing down the cost of solar cells (Duke & Kammen, 1999; Swanson, 2004). But how much had learning-by-doing effects affected solar costs by the mid 2000s? When Nemet (2006) from the Energy and Resources Group at the University of California had disentangled these factors, he had found that learning-by-doing innovations contributed only slightly to solar cell cost reductions over the previous thirty years. His results had indicated that learning from experience "only weakly explains change in the most important factors - plant size, module efficiency, and the cost of silicon" (Nemet, 2006).

6.5 Greenhouse gases

Perhaps no single benefit of solar cells was more cherished than their apparent ability to reduce CO_2 emissions. In 2007, a group of Columbia University scholars had calculated a solar cell's lifecycle carbon footprint at twenty-two to forty-nine grams of CO_2 per kilowatt-hour (kWh) of solar energy produced (Fthenakis & Kim, 2007; De Decker, 2008). This carbon impact was much lower than that reported for fossil fuels at the time (De Decker & Grosjean, 2008). Did this offer justification for subsidizing solar panels as a carbon reduction mechanism?

Analysts at the time might have begun by considering the market price of avoiding greenhouse gases such as CO_2. In 2008, solar technologies would have competed with coal only if carbon credits had risen to three hundred dollars per ton. Photovoltaics could have nominally compete with natural gas only if carbon offsets had skyrocketed to six hundred dollars per ton. It is difficult to conceive of conditions that would have thrust CO_2 prices to such stratospheric levels in real terms. Even some of the most expensive options for dealing with CO_2 at the time would have presumably become cost competitive long before solar cell technologies. If limiting CO_2 was the goal, then legislators might presumably have envisioned a much larger impact by directing stimulus funds to home insulation, industrial efficiency, and related strategies. By the carbon numbers alone, solar cells would have seemed a wasteful and pricey strategy.

Even then, solar manufacturing and deployment operations were already known emitters of hexafluoroethane (C_2F_6), nitrogen trifluoride (NF_3), and sulfur hexafluoride (SF_6). Used for cleaning plasma production equipment, creating castings, insulating high voltage transmission lines, and other applications, these three gruesome greenhouse gases made CO_2 seem harmless. As a greenhouse gas, C_2F_6 was understood to be twelve thousand times more potent than CO_2, 100 percent manufactured by humans, and to survive ten thousand years once released into the atmosphere (IPCC, 2003; Conniff, 2008). NF_3 was understood to be seventeen thousand times more virulent than CO_2, and SF_6, the most treacherous greenhouse gas, according to the Intergovernmental Panel on Climate Change, had been calculated to be twenty-four thousand times more threatening (Weiss et al., 2008). Due to its need for high-tech fabrication techniques and long-distance transmission from remote desert areas, the solar industry might have been seen as a significant emitter of exotic greenhouse gasses, especially on a per-kWh basis. Exotic greenhouse gas emissions were nominally small compared to other greenhouse gasses but were nevertheless quickly accumulating within the earth's atmosphere. A study on NF_3 reported that atmospheric concentrations of the gas had been rising an alarming 11 percent per year (Weiss et al., 2008). The Sunrise Powerlink Project, which connected several desert solar arrays to metropolitan areas in southern California, employed SF_6 as an insulator. According to the California Public Utilities Commission (2008, p. ES-25), the "electrical equipment associated with the new transmission system would result in the potential escape of sulfur hexafluoride (SF_6), and because the proposed transmission system equipment would cause a net increase in SF_6 emissions, this impact would be significant and unavoidable." If solar cell installations had been seen to multiply by 100 to 1000 fold, as proponents anticipated, would they not have expected these exotic greenhouse gasses to increase as well?

6.6 Durability

By 2007, The United Arab Emirates had completed the largest cross-comparison test of photovoltaic modules ever attempted in preparation for building their eco-metropolis called Masdar City. The project's technicians had installed forty-one solar panel systems from thirty-three different manufacturers in the desert near Abu Dhabi's international airport (Masdar, 2007). They had designed the test to differentiate between cells from various manufacturers, but once the project was initiated, it had quickly drawn attention to something else - the drawbacks that all of the cells shared, regardless of their manufacturer.

Solar cell firms generally tested their panels in the most ideal of conditions - a Club Med of controlled environments. The real-world desert outside Masdar City had proved less accommodating. Atmospheric humidity and haze had reflected and dispersed the sun's rays. Even more problematic was the dust, which technicians had to scrub off almost daily. Researchers had discovered that soiling routinely cut electrical output of a San Diego site by 20 percent during the dusty summer months. Bird droppings, shade, leaves, traffic dust, pollution, hail, ice, and snow were also known factors (LaMonica, 2004; Kimber et al., 2006).

When journalists had toured Masdar's test site, they visited the control room that provided instant energy readouts from each company's solar array. On that late afternoon, the journalists had noted that the most productive unit had been yielding four hundred watts and the least productive under two hundred. All of the units were rated at one thousand watts maximum. Such peak output, however, could only theoretically occur briefly at midday, when the sun was at its brightest, and only if the panels were located within an ideal latitude strip and tilted in perfect alignment with the sun (and all other conditions are near perfect as well). The desert outside Masdar City might have seemed like one of the few ideal locations on the planet for such perfection. However, during the midday hours of the summer, all of the test cells became extremely hot, up to 176 degrees Fahrenheit (80°C), as they baked in the desert sun. Due to the temperature sensitivity of the photovoltaic cells, their output had been markedly hobbled across the board, right at the time they should have been producing their highest output (Stanton, 2008).

In addition to haze, humidity, soiling, misalignment, and temperature sensitivity, it was well understood within the industry and scientific literature that silicon solar cells suffered an aging effect that eroded their output by about 1 percent or more per year. The newer thin-film, polymer, paint, and organic solar technologies were degrading even more rapidly, with some studies recording degradation of up to 50 percent within short periods of time. This potential limitation, however, was regularly concealed because of the way reporters, corporations, and scientists presented these technologies (Jørgensen, Norrmana, & Krebs, 2008; Meyer & van Dyk, 2004). For instance, a thin-film panel achieving, say, 13 percent overall efficiency in a laboratory might have only achieved a 10 percent overall efficiency in a prototype due to production limitations. In the field this was presumed to drop to about 7-8.5 percent overall efficiency due just to degradation effects according to the industry (Solarbuzz, n.d.). Still, the direct current (DC) output was not usable in a household until transformed through inverters, which were about 70-95 percent efficient. Still, when laboratory scientists and corporate PR teams wrote press releases, they reported the more favorable efficiency figure, in this case 13 percent.

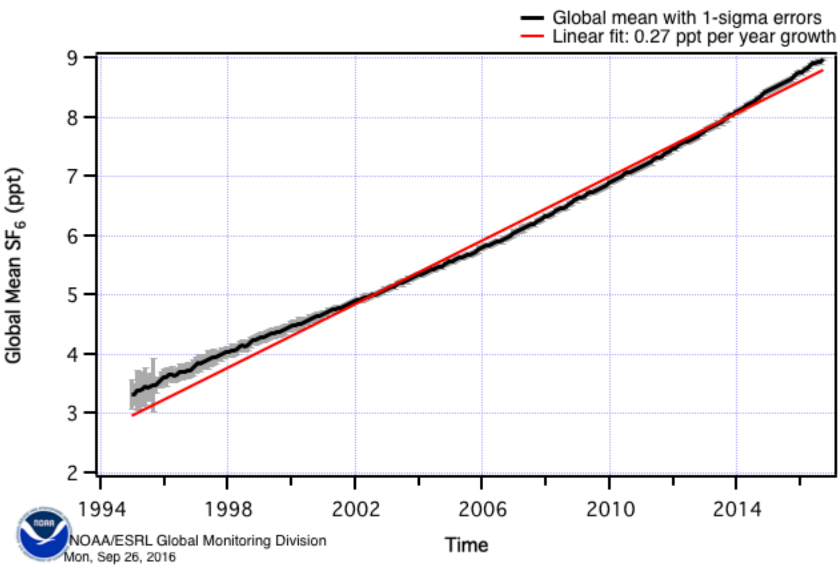
Journalists at even the most esteemed publications often simply transposed such figures into their articles. Engineers, policy analysts, economists, and others in turn transposed the figures into their assessments. In one sense this generation of ignorance could be classified as strategic, in that it immediately benefited the careers of the lab investigators and the prestige of the university to tout findings in the most favorable light. But in these sections we can begin to see the interdependence of solar symbolism with forms of broader institutional amnesia concerning field data as well as ignorance arising through subsequently undone science. In the next chapter, we will explore in more detail the value of such material and *in situ* ignorance to the various interests involved in clean technology innovation.

6.7 A material semiotic reckoning

Collected and assembled into one material narrative, the field data as they were understood in California and Masdar City at the time of the 2008 crisis, become particularly intriguing in retrospect. The point here is not to label competing claims about solar cells as simply true or false, based on knowledge or on ignorance (we have seen they are a bit of both), but to question whether the materially borne attributes of these technologies at the time had manifested themselves in ways and to degrees that could have, in their own right, presumably validated solar photovoltaics as an appropriate means to achieve global environmental goals. Or, might we impart that there existed a degree of semiotically induced ignorance to the experience-based effects, costs, construction, and other material factors? Was such ignorance perhaps even necessary for the prioritization of these technologies over, say, energy reduction strategies?

Governments, investors, concerned citizens, nonprofits, and others would eventually commit hundreds of billions of dollars to the solar dream in the years following the global economic crisis. In 2010, one group announced plans to build solar breeder facilities in the Sahara desert to convert desert sand into solar arrays, which would then in turn power additional facilities to dig up more sand to do the same. In 2011, the CEO of Praxair, a major supplier of numerous industrial gasses, including the virulent greenhouse gas sulfur hexafluoride, opened the company's annual report with a letter highlighting the photovoltaic industry as one of its most impressive growth sectors (Angel, 2011). Up until around 2008 sulfur hexafluoride concentrations in the atmosphere had been growing linearly. Afterward, the growth shifted from linear to exponential growth. Interestingly, NOAA continued to release its SF_6 reports using a linear model, even though it apparently no longer fit the data. In 2012, the solar industry in Europe peaked then collapsed under the weight of higher than assumed costs, higher than assumed degradation, and lower than assumed output. The cash lasted longer in the United States, but the largest solar plant was underperforming, frying birds, bats, and bugs, and had to ask the state for permission to use more fossil fuel to start up in the morning and keep the plant going.

Figure 6.1: In 2011, the gas industry giant Praxair identified solar cells as a growth sector for its specialty gasses such as sulfur hexafluoride which has a climate impact 24,000 times higher than CO_2 according to the IPCC. Up until around 2008 sulfur hexafluoride concentrations in the atmosphere grew linearly. Since then, atmospheric concentrations shifted gears from linear to exponential growth. Image courtesy of NOAA



As an exercise, I'd like to consider how these material considerations of solar energy might be interpreted through an altered frame. What if we interpreted the powerful symbolism of solar cells as metastasizing in the minds of thoughtful people into a semiotic structure of belief? For instance, could we read these technologies as embodying lucrative forms of semiotically induced ignorance - shiny sleights of hand that allow oil companies, for example, to convince motorists that the sparkling arrays atop filling stations somehow make the liquid they pump into their cars less toxic? Might large fossil fuel companies choose to produce solar cells in an attempt to be seen as "cleaner" and "greener?" The bigger the sin, the greater the need for atonement? Further, we might question how politicians rely on the symbolic value of solar cells to boost their poll numbers in one hand while using the other to advance "economic growth," jobs, and extractive industries that feed solar lifecycles. We have seen tension between the semiotic signifier and the signified, plausibly maintained through layers of non-knowledge, which may insulate symbolic impressions from the material attributes of energy technologies. This may manifest in more abstract structural forms as well. Consider that many homeowners are keen on upgrading to solar, but because the panels require large swaths of unobstructed exposure to sunlight, solar cells often end up atop large homes sitting on widely spaced lots cleared of surrounding trees – trees which could have offered considerable passive solar benefits. In this respect, the symbolic imperative of solar cells acts to obscure a the structural character of suburban residential construction that might otherwise be understood as an unsustainable car-dependent community model. This brings up a concluding question; might the promise of solar cells act to prop up a productivist mentality more broadly, one that insists that humanity can simply generate more and more power to satisfy expansion? (see Gibbs, 2020; Goldblatt, 2005) We will pick up this point at the end of the next chapter and in Chapter 8.

Chapter 7: Contextual limitations to wind power and the boomerang effect

This chapter is the final of the four chapters presented as case manuscripts. Originally written for a non-specialist audience, this chapter is a lightly edited version of my second chapter of Green Illusions (Zehner, 2012). As a special note, section 7.7 is an exposé on industry involvement (through the American Wind Energy Association) in crafting an ostensibly independent government assessment of wind energy. This investigation was first published in 2012. The American Wind Energy Association issued a response but did not deny the central implication of the research claiming that the American Wind Energy Association was in effect the author of the report, which was presented as a government study. Three years later, in April of 2015, the Senior Director of Federal Legislative Affairs for the American Wind Energy Association revealed that the characterization was accurate, referring to the Department of Energy Wind Vision report as "our" report in a private email to supporters, which was forwarded to me by a journalist. The original exposé is included here in section 7.7.

Overall, this chapter explores the import of symbolic associations into the political process. What are the unintended consequences of wind turbine developments in context and what implications do these hold for the displacement of fossil fuels more broadly? We will also compare the nameplate capacity of solar and wind technologies to their actual production in context. We will see that the two valuations vary dramatically. What political opportunities does this variance create for selective knowledge in translating green symbols into actual policy actions?

7.1 The case for wind power

By the end of grade school, my mother maintains, I had attempted to deconstruct everything in the house at least once (including a squirrel that fell to its death on the front walk). Somewhere in the fog of my childhood, I shifted from deconstruction to construction, and one of my earliest machinations was a windmill, inspired by a dusty three-foot-diameter turbine blade laying idle in the garage thanks to my father's job at a fan-and-turbine manufacturer. Fortunately, the turbine's hub screws fit snugly around a found steel pipe, which formed a relatively solid, if rusty, axle for the contraption. I mounted the axle in wood rather than steel, since my parents had neglected to teach me to weld. There were no bearings, but I dusted the naked holes with powdered graphite for lubrication; I was serious. Lacking the resources to design a tower, a wood picnic table in the backyard proved sufficient.

Some subsequent windy day I hauled the rickety contraption from the garage to the picnic table. I first pulled the wooden mount up onto the table, weighing it down with bricks and other heavy objects. I then inserted the axle-and-turbine assembly. The already rotating blades hovered out over the table's edge, but there was little time to appreciate my work. Before the lock pin was properly secured, the heavy blade had already begun to spin uncomfortably fast. Only at that moment did it become apparent that I had neglected to install a braking mechanism, but it was too late.

I removed a brick from the base and pressed it against the rotating axle to slow it down, pushing with all my might. The axle hissed as the blades effortlessly accumulated greater speed. I jumped back when the axle's partially engaged lock pin flew out. The picnic table vibrated as the dull black blades melted into a grayish blur. The steel sails thumped through the air with a quickening rhythm of what in essence had become an upended lawnmower. What happened thereafter can only be deduced, because by the time the howling and clamor came to an abrupt end, my adrenaline-filled legs had already carried me well beyond the far side of the house. I returned to find an empty picnic table in flames.

Now, if we imagine a force ten thousand times as strong, we can begin to appreciate the power of modern wind turbines, weighing in at 750 tons and with blade sweeps wider than eleven full-size school buses parked end-to-end. Like solar cells, wind turbines appear to run on a freely available resource that is exhibiting no signs of depletion.

Today's wind turbines are specially designed for their task and as a result are far more technologically advanced than even those built a decade ago. New composites enable the spinning arms to reach farther and grab more wind while remaining flexible enough to survive forceful gusts. New turbines are also more reliable. In 2002, about 15 percent of turbines were out of commission at any given time for maintenance or repair; now downtime has dropped below 3 percent. Whereas a coal or nuclear plant mishap could slash output dramatically or even completely, wind farms can still pump out electricity even as individual turbines cycle through maintenance. Similarly, new wind farms start to produce power long before they are complete. A half-finished nuclear plant might be an economic boondoggle, but a half-finished wind farm is merely one that produces half the power. Adding capacity later is as simple as adding more turbines. Farmers who are willing to give up a quarter of an acre to mount a large turbine in their fields can expect to make thousands of dollars per year in profit without interrupting cultivation of the surrounding land. At first glance, deploying wind turbines on a global scale does not apparently pose much of a challenge, at least not an insurmountable one. It seems that no matter what yardstick we use, wind power is simply the perfect solution. If only it were that simple.

7.2 The history of wind power

As our sun heats the earth's lower atmosphere, pockets of hot air rise and cooler air rushes in to fill the void. This creates wind. For over two thousand years humans harnessed wind for pumping water, grinding grain, and even transatlantic travel. In fact, wind power was once a primary component of the global energy supply. No more. During the Industrial Revolution shipbuilders replaced masts, in short supply due to the deforestation, with coal-fired steam engines (Perlin, 2005). Farmers abandoned windmills for pumps that ran on convenient fossil fuels.

The oil embargo of 1973 marked the resurrection of wind power (Gipe, 1995). During the great wind rush of the early 1980s, California housed nearly 90 percent of global wind-generation capacity, fueled by tax subsidies and a wealthy dose of sunny optimism ("Case History," 2008). And since the windmill industry had vanished long ago, fabricators cobbled together the new turbines much like the one of my youth, with an existing hodgepodge of parts already available from shipbuilders and other industries (Manwell, 2010). Perhaps predictably, when the oil started to flow again, political support for wind energy subsidies waned. Eventually they vanished altogether. During the first decade of the twenty-first century, oil prices skyrocketed. But another phenomenon shot up faster: media and political reporting on wind energy. As detailed in Chapter 3, for every doubling of oil prices, media coverage of wind power tripled. Capacity grew too - as much as 30 percent annually.

7.3 The detractors

Not everyone liked wind power. "A boot tumbling around in a clothes dryer" - is how residents of Cape Cod described the wind turbine whining and thumping that kept them awake at night and gave them headaches during the day. Multiple turbines can orchestrate an additive effect that is especially maddening to nearby residents. The fact that there is already a condition recognized as "wind turbine syndrome" testifies to the seriousness of their protest. In addition to noise, detractors point to various other grievances. For instance, turbine blades occasionally ice up, dropping or throwing ice at up to two hundred miles per hour. They may also toss a blade or two, creating a danger zone within a radius of half a mile (Myers, 2010). Beyond this zone, residents are relatively safe from harm, and outside a one-mile radius the racket of wind turbines diminishes to the level of a quiet conversation. Ideally energy firms would not build wind turbines near homes and businesses but many of the other prime windy locations are already taken, geologically unstable, inaccessible, or lie within protected lands such as national parks. As a result, desperate wind power developers are already pushing their turbines both closer to communities and out into the sea, a hint as to limitations ahead.

Environmentalists sometimes find themselves caught in the mix. For instance, during the 1980s, the Sierra Club rose in opposition to a wind farm proposed for California's Tejon Pass, citing risks to the California condor, an extinct bird in the wild that biologists were planning to reestablish from a small captive group. A Sierra Club representative quipped that the turbines were "Cuisinarts of the sky," and the label stuck. Detractors passionately cite the dangers to birds and bats as giant blades weighing several tons, their tips moving at two hundred miles per hour, spin within flight paths. However, proponents argue newer turbine models spin more slowly, making them less a threat. Their smooth towers are less appealing for nesting than the latticed towers of earlier designs. According to one study, each turbine kills about 2.3 birds per year, which, even when multiplied by ten thousand turbines, is a relatively small number compared to the four million birds that crash into communication towers annually, or the hundreds of millions killed by house cats and windows every year (Lucas, Janss, & Ferrer, 2004; Whittelsey, 2007). Even the Sierra Club grew less concerned, pointing out that progress is being made to protect many bird habitats and that turbine-related death "pales in comparison to the number of birds and other creatures that would be killed by catastrophic global warming" (Whittelsey, 2007). The Sierra Club's evolved position on wind turbines is indicative of a shift in focus within the mainstream environmental movement - toward a notion that technologies such as wind turbines will mitigate climate change and related environmental threats posed by fossil-fuel power plants. One largely unaddressed question in the literature is what evidence undergirds this assumption? And, has it borne out in practice?

7.4 Considering carbon

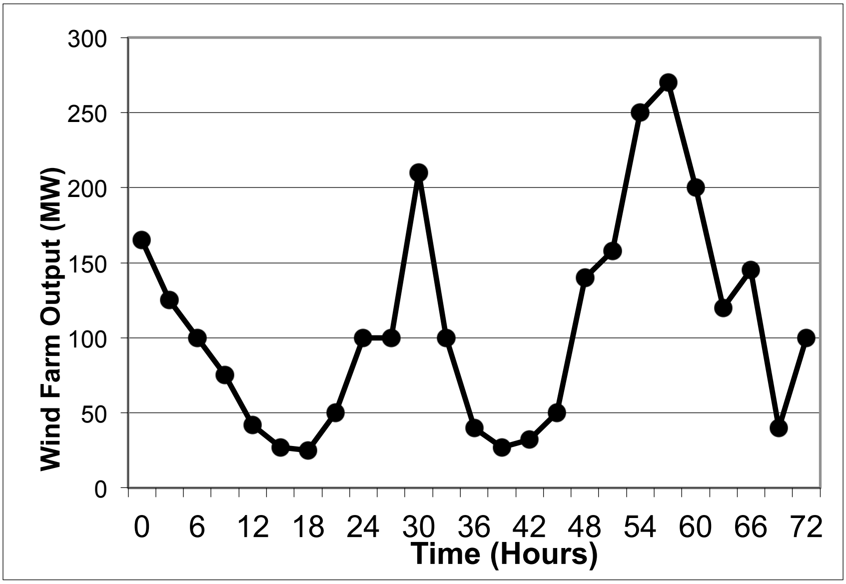
Wind proponents are keen to proclaim that their turbines don't spew carbon dioxide. But is this the answer to an unsatisfactory question? Turbines may not exhaust CO_2 directly but lifecycle calculations reveal that wind power technologies actually rely heavily on fossil fuels, which is why they are so expensive build, a consideration with ramifications we will revisit in the last chapter. In practice, does this leave so-called renewable wind power as a mere fossil-fuel hybrid? This spurs some further questions. First, if fossil-fuel and raw-material prices pull up turbine costs, to what degree can nations rely on wind power as a hedge against scarcity of their constituent natural materials? Moreover, where will the power come from to build the next generation of wind turbines as earlier ones retire from service? Will we simply have to fall back on fossil fuels? Wind is renewable. Turbines are not. Nevertheless, wind is a freely available resource around the globe, it doesn't have to be mined, and we don't have to pay to have it imported. There is, however, one little issue - one that is causing headaches on a monumental scale - which will lead us closer to understanding the biggest limitation of wind power. Occasionally, wind has been known to stop.

7.5 A Frustratingly unpredictable fuel

Imagine if your home's electrical system were infested by gremlins that would without warning randomly vary your electrical supply - normal power, then half power, then three-quarter power, then off, then on again. Some days you'd be without electricity altogether and on others you'd be overloaded with so much current your appliances would short circuit and perhaps even catch on fire. This is the kind of erratic electrical supply that wind power grid operators deal with on a minute-to-minute basis. Whenever the wind slows, they must fire up expensive and inefficient peaker power plants in order to fill the supply gap. Even when the wind is blowing, they often leave the plants on idle, wasting away their fossil fuels so they're ready when the next lull strikes. To make matters worse, grid operators must perform these feats atop a grid of creaky circuitry that was designed decades ago for a far more stable supply.

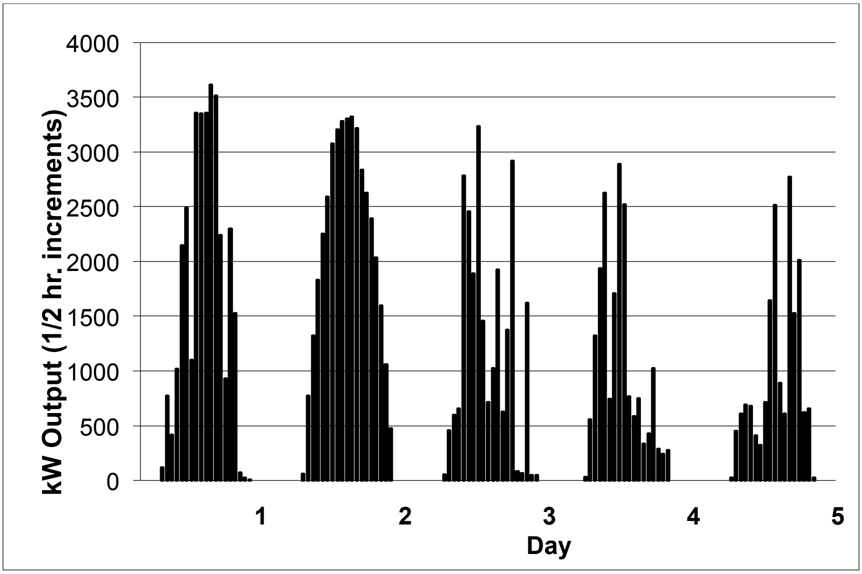
Traditional coal, natural gas, nuclear, and hydroelectric power stations provide a steady stream of power that operators throttle to match demand. Conversely, wind and solar electrical output varies dramatically. Windy periods are especially difficult to predict. Even when the wind is blowing more consistently, wind turbines encounter minor gusts and lulls that can greatly affect their minute-to-minute output. Over still periods, wind turbines can actually suck energy off the grid since stalled turbines require electrical power to operate their massive steering systems and other idling functions such as powered rotation to prevent their heavy axels from warping due to gravity.

Figure 7.1: Wind farm output varies unpredictably. This chart shows the output of a large South Australian wind farm (in megawatts) over seventy-two hours. (Data from Tom Quirk)



Solar radiation is more predictable in frequency but not in intensity, as shown in Figure 7.2. Even on mostly sunny days, solar photovoltaic output can vary due to dust, haze, heat, and passing clouds (Apt & Curtright, 2008).

Figure 7.2: This plot shows the output (in kilowatts) of a large photovoltaic system in Springerville, Arizona, over five days. Heat, haze, clouds, and other factors affect minute-to-minute solar output unpredictably. (Data from Tucson Electric Power Company)

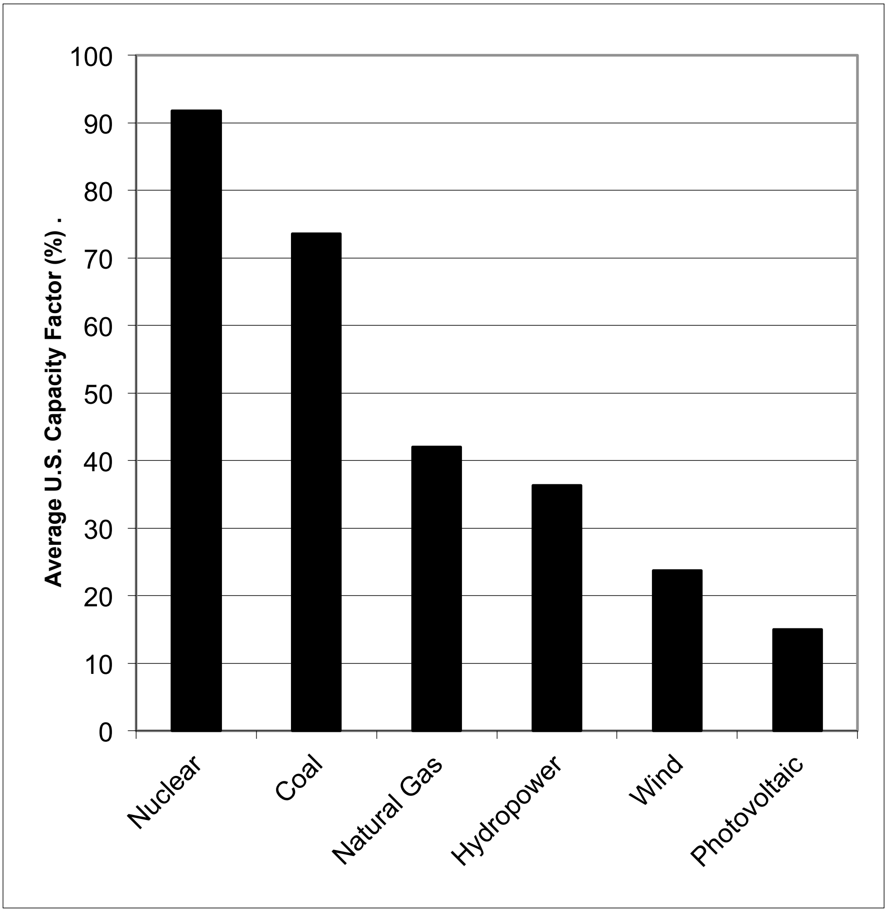


Grid operators can handle small solar and wind inputs without much problem (they manifest as small drops in demand). However, significant unpredictable inputs can endanger the very stability of the grid. Therefore, wind power isn't well suited to supply base-load power (i.e., the power supplying minimum demands throughout the day and night). If operators relied on wind power as a base-load supply, traffic signals, hospitals, and other essential services would be cut whenever the wind stopped. Even though wind power companies employ teams of meteorologists to predict wind speeds on an hour-to-hour basis, they still rely on coal, natural gas, hydroelectric, and nuclear power plants running alongside them for consistency. Proponents frequently declare that wind power costs the same as fossil fuel power, but alternative-energy firms often aren't required to back up their temperamental products, which makes them seem less pricey than they are in practice. It is during the power conditioning steps that the total costs of wind power start to multiply. The inconsistency of wind power necessitates a dual system, the construction and maintenance of one power network for when the wind is blowing and a second network for when it isn't - an incredibly expensive luxury. This presents an opportunity to mobilize ignorance of energy quality through comparing varying qualities of power conversion, wind versus coal for instance, as if they are equivalent and interchangeable - a kilowatt for a kilowatt – when no basis for such a comparison could be formulated through a fuller knowledge of the difference.

7.6 Capacity versus production

A power plant's maximum output is termed "nameplate capacity," while the actual output over time is called "production." A "capacity factor" indicates what percentage of the nameplate maximum capacity a power plant actually produces over time. In traditional plants, operators control production with a throttle. A small one-hundred-megawatt coal plant will only produce 74 percent of that amount on average, or seventy-four megawatts (Energy Information Administration, n.d.). A large wind farm with a nameplate capacity of one hundred megawatts will produce just twenty-four megawatts on average since the wind blows at varying strengths and sometimes not at all ("Existing capacity," n.d.). The difference between capacity and production is simple, yet these two measures are confused, conflated, and interchanged by journalists, politicians, and even experts. In the next section, we will question how ignorance involving energy quality, interchangeability, capacity, production, and other factors can influence and even advance political support for and mobilization of wind energy infrastructure.

Figure 7.3: A capacity factor is the percentage of the nameplate maximum capacity that a power plant actually produces over time. Fossil fuel, hydro, and nuclear plants attain nearly 100 percent of maximum capacity when fully throttled, but lulls in demand and cost differentials leave them producing less. Natural gas is more expensive than coal, so power companies turn off gas plants first when demand drops. Weather variables dictate wind and photovoltaic capacity factors. (Data from U.S. Department of Energy)



7.7 Manufacturing strategic ignorance

When President Obama premiered his clean energy initiative in Newton, Iowa, he cited a prominent U.S. Department of Energy (DOE) report showing that the nation could easily obtain 20 percent of its electricity from wind turbines by 2030 - he may have been completely unaware that the report's key dataset wasn't from the DOE at all. In fact, if genuine DOE cost and performance figures had been used, the report's authors would likely have come to the opposite conclusion - 20 percent wind by 2030 will be logistically complex, enormously expensive, and perhaps ultimately unachievable.

Much of the enthusiasm in the United States surrounding wind grew out of a prominent Bush-era report entitled *20% Wind Energy by 2030*, which concluded that filling 20 percent of the nation's grid with wind power is achievable and will come at a cost described as "modest." The authoritative DOE report has been held up as a model for charting a course for wind energy funding; it has been covered by media sources across the globe, presented to congressional leaders, evoked by two presidents, and supported by the Sierra Club, the Worldwatch Institute, the Natural Resources Defense Council, and dozens of other organizations (U.S. Department of Energy, 2008). In fact, during my investigative research on the study, I didn't come across a single critical review of its findings. It is therefore particularly intriguing to note that the report is based on key assumptions, hidden within a second appendix, which are so explicitly incongruent with bona fide DOE data that many people might have considered them to be outright fraudulent had they not been produced within the protective halo surrounding alternative-energy research.

The report's most remarkable conclusion is simple. Filling 20 percent of the grid with wind power over the next twenty years will cost just 2 percent more than a scenario without wind power (U.S. Department of Energy, 2008). The conclusion builds upon cost and performance figures developed by industry consultants, despite the fact that the DOE already spends millions of dollars tabulating the same sorts of data on a routine basis. The report cites four "major" contributors outside the Department of Energy: a trade organization called American Wind Energy Association (AWEA) and three consulting firms - Black and Veatch, Energetics Incorporated, and Renewable Energy Consulting Services. Would perhaps any one of these groups have something to gain from painting an optimistic rendering of wind's future? It turns out they all do. And that potential gain can be measured in billions.

When the report was written, the AWEA's board of directors included executives from General Electric, JP

Morgan, Shell, John Deere, and a handful of wind power companies including T. Boone Pickens's company Mesa Power. As an industry group, the AWEA was interested in orchestrating a positive spin on anything wind. The AWEA salivated in anticipation of preparing a pro-wind report enshrouded by the credibility of the Department of Energy.

But, there was a problem.

The DOE's field data on wind turbine performance was presumably too grim - too realistic perhaps - for a report destined to showcase the future of wind power. Far more favorable statistics would be required. And the consultant employed to produce the stand-in datasets, which we might think of as a deployment of instrumental ignorance, would not disappoint.

The authors retained Black and Veatch - a consultancy that designs both wind farms and natural-gas generation plants - to develop cost projections as well as key capacity factors for the analysis (for information on B&V, see: http://www.bv.com/; for B&V contributions, see: U.S. Department of Energy, "20% Wind Energy by 2030: Increasing Wind Energy's Contribution to the U.S. Electrical Supply."). Remember, a capacity factor is simply the percentage of a wind turbine's nameplate capacity that is actually produced under real-world conditions - the difference of a percent or two can make or break a wind farm. According to DOE data, when countries or regions start to install wind turbines, the average capacity factor goes up at first, then levels off or declines as additional turbines are sited in less-ideal locations (U.S. Department of Energy, 2009). For instance, between 1985 and 2001, the average capacity factor in California rose impressively from 13 percent to 24 percent, but has since retreated to around 22 percent. Over recent years, Europe's maturing wind farms have stabilized below 21 percent (Boccard, 2009). The U.S. average is under 26 percent, according to field readings from the DOE. That is why Black and Veatch's capacity-factor assumptions, starting at 35 percent to 52 percent in 2010, and continuing to increase 15 percent by 2030, are particularly shocking.

Black and Veatch's average capacity-factor estimations rank among the highest ever published anywhere, let alone in a formal government report. If Black and Veatch knows how to run the worlds turbines at such high capacity, then they appear to know something that nobody else does. Even the pro-wind AWEA caps realistic capacity factors at a terribly optimistic 40 percent - so, incidentally, does the Department of Energy (American Wind Energy Association, n.d.). In fact, Black and Veatch's expectation that capacity factors for wind turbines will increase over the next twenty years conflicts with other DOE reports, which forecast turbulence as future wind farms are forced into subprime locations (U.S. Department of Energy, 2009).

The knowledgeable public servants at the DOE might have laughed Black and Veatch out of Washington. But they didn't. They got them published.

The justifications for employing such extraordinary assumptions are not entirely clear. During my research, a DOE official assured me that the Black and Veatch figures "were extensively critiqued and adjusted by experts in the wind and general energy communities." Though when I asked a director at Black and Veatch why their figures differed so dramatically from DOE assumptions, he was rather tight-lipped, insisting only that they stood by the methodology as outlined in the report (author interview with Liz Hartman, 2009; author interview with George Minter, 2009). That is particularly disconcerting.

The report's methodology section states simply, "Black and Veatch used historical capacity factor data to create a logarithmic best-fit line, which is then applied to each wind power class to project future performance improvements." It seems the consultancy assumed that the wind turbine learning curve (i.e., the idea that past experience with a technology helps to improve the technology and reduce its costs) would continue to produce gains well into the future. While it is well accepted that this occurred through the 1980s and 1990s, the learning curve has since flattened, as the DOE had documented (U.S. Department of Energy, 2009). Therefore, extrapolating a select few years of data into the future without acknowledging the industry's maturation is as problematic as extrapolating the growth of high school students to show that by college they will stand taller than giraffes.

In addition to the optimistic capacity-factor projections, the report's analysis includes mysterious historical data. Black and Veatch "estimated" capacity factors ranging from 32 percent to 47 percent in 2005 (U.S. Department of Energy, 2008a). The report fails to mention that DOE fieldwork from that year placed the actual nationwide capacity factor closer to 20 percent (see also Boccard, 2009). When I asked Black and Veatch about the discrepancy, they offered no further comment. These discrepancies aren't the only surprises lurking in the report's appendices.

Black and Veatch assumed that the costs for building, installing, and maintaining future wind turbines would not increase, as other DOE reports predicted, but would actually decrease, due to what it "black boxed" as "technology development." But since newer turbine designs were already close to their theoretical maximum efficiency, the future success of wind power might have been understood as less influenced by technological development than by social and environmental variables.

When Black and Veatch's capacity-factor assumptions were compounded by their cost assumptions, readers were left with an impression of wind power that was up to six times more impressive than if the analysis were run using the DOE's own figures. This raises a question; why did the Department of Energy base its pivotal wind energy report on numbers conjured by an engineering firm, with a vested interest in advancing energy production interests, rather than its own data? This is the question I posed to the DOE.

Their response was telling. They made it apparent that even though the report claims to contain "influential scientific information," its analyses might not be flattering to the greater scientific community (U.S. Department of Energy, 2008a). One of the report's lead editors told me, "The 20% Wind work was carried out to develop a picture of a future in which 20 percent of the nation's electricity is provided from the wind, and to assess the feasibility of that picture. The work was based on the assumption that reasonable orderly advancement of the technology would continue, and that key issues needing resolution would be addressed and favorably resolved. Hence the work used input information and assumptions that were forward-looking rather than constrained by recent history" (author interview with Liz Hartman, 2009).

Indeed, the authors did not allow recent history to stand in their way. In fact, some might argue that their answer echoes the rhetoric used to defend the fabrication of data for which no historical justification or cultural context exists. Energy players employed such lines of reasoning to suggest that by the 1960s, nuclear energy would produce abundant clean energy for all, that by the 1970s, fusion power would be too cheap to meter, and that solar cells would be fueling the world's economies by 1986 (Sherden, 1998; Penley, 1997; Del Sesto, 1987; Sarewitz, 1996; Ravetz, 1971).

Boccard (2009; 2010) found that when solid data do not exist, wind proponents are all too willing to make "unsubstantiated guesses" and get away with it because the public, politicians, journalists, and even many energy experts don't understand how capacity factors are involved in influencing prospects for wind power development. Or, perhaps caught up in the excitement surrounding wind energy, proponents may simply not care, due to a psychological phenomenon called selection bias, whereby people tend to overvalue information that reinforces their ideology and undervalue that which contradicts it. Boccard insists, "We cannot fail to observe that academic outlets geared at renewable energy sources naturally attract the authors themselves supportive of renewable energy sources, as their writing style clearly indicates. As a consequence, this community has (unconsciously) turned a blind eye to the capacity factor issue." Boccard compared wind farm data across many European countries, where wind power penetration is many times higher than in the United States, and uncovered a worrisome gap between the anticipated and realized output of wind turbines. In fact, Boccard maintains, the difference was so large that wind power ended up being on average 67 percent more expensive and 40 percent less effective than researchers had predicted. As a rule of thumb, he maintains that any country-level assumptions of capacity factors exceeding 30 percent should be regarded as "mere leaps of faith" (Boccard, 2009).

It might seem counterproductive for wind firms to risk overinflating expectations, but consulting firms such as Black and Veatch stand to lock in profits during the study and design phase, long before the turbines are even brought online. Turbine manufacturers stand to gain from the sale of wind turbines, regardless of the side effects they produce or the limitations they encounter during operation. If the turbines don't return on the promise, it is not necessarily a risk for those in the money. The real challenge is presumably convincing the government, and ultimately taxpayers, into covering as much of the bill as possible. And one of the best tools for achieving that objective? A report that can be summarized in a sound bite struts with an air of authority and can glide off the president's tongue with ease: *20% Wind Energy by 2030*.

It may be tempting to characterize this whole charade as some sort of cover-up. But the Department of Energy officials I interviewed were certainly open (if nervous) to my questions; anyone with an Internet connection could access the report and its suspect methodologies; and the DOE regularly publishes its field measurements in a report called the Annual Energy Outlook. There's no secret. Energy corporations develop "forward-looking" datasets favorable to their cause; government employees slide those datasets into formal reports; the Department of Energy stamps its seal on the reports; and the Government Printing Office publishes them. Then legislators hold up the reports to argue for legislation; the legislation guides the money; and the money gets translated into actions - usually actions with productivist leanings. It isn't a cover-up. It is standard operating procedure. This process nevertheless leads to a certain type of policy development - one that is intrinsically predisposed to favor energy production over energy reduction. When Big Oil companies leverage questionable science to their benefit, environmentalists fight back en masse. But when it comes to the mesmerizing power of wind, they acquiesce. No op-eds. No investigative reports. No magazine covers. Nothing. If environmentalists suspected anything funny about the 20% Wind Energy by 2030 report, they didn't say anything about it in public. Instead, fifty environmental groups and research institutes, including the Natural Resources Defense Council, Sierra Club, and Lawrence Berkeley National Laboratory opted to double-down their windy bets by formally backing the study.

Every energy-production technology carries its own yoke of drawbacks and limitations. However, might the allure of a magical silver bullet act to prop up and stabilize a system of extreme energy consumption and waste? If clean and abundant energy is just over the horizon, is there less motivation to clean up existing energy production or use energy more wisely? It is not uncommon for a government to maintain two ledgers of incompatible expectations. One set, based on fieldwork and historical trends, is used internally by people in the know. The second set, crafted from industry speculation and "unconstrained" by history, is disseminated via press releases, websites, and even by the president himself to an unwitting public.

Here, we have witnessed an unusually stark example of how ignorance can be valuably used instrumentally and in an applied manner to advance development of an energy technology, in this case taking it from the bench to the field on a large scale. Following the publication of the report, hundreds of billions of dollars flowed into the wind power sector, to support everything from basic research to turbine installations. The use of DOE field data might very well have been inadequate to create the impression required in order to mobilize such funds. Interested parties can advance technological industrialization by drawing upon valuable forms of contextual and strategic ignorance, which when applied, can mobilize non-knowledge into a credible form, such as a dataset, expert testimony, or government report. This credible form can provide a means of transfer of the subject non-knowledge to initiate funding, motivate public support, and mobilize implementation of the technology on a far larger scale than might have been otherwise realized.

7.8 Boomerang effect

Even if the United States, or any other nation, could attain 20 percent wind energy by 2030, the achievement alone might not remove a single fossil-fuel plant from the grid. There is a common assumption that building additional alternative-energy capacity will automatically displace fossil-fuel use on a one-to-one basis; however, over past years, this hasn't been the case (York 2012; 2016). Could producing more energy through alternate means simply increase supply, lower cost, and stimulate additional energy consumption – a boomerang effect? Might subsidized wind turbines and solar cells, if they were to produce net energy, simply expand energy supplies and place downward pressure on prices? Might this in turn spur demand, entrench energy-intensive modes of living, and finally bring us right back to where we started: high demand and so-called insufficient supply? In short, do we risk creating an energy boomerang - the harder we throw more power into the grid, the harder the boomerang of demand will come back to hit us on the head? Are more efficient solar cells and taller wind turbines just ways of throwing the boomerang harder? If this were the case in the existing global expansionist context, increasing alternative-energy production might not displace fossil-fuel side effects but instead simply add more side effects to the mix. Instead of a world with just the dreadful side effects of fossil fuels, might we enter into a future world with the dreadful side effects of fossil fuel *plus* the dreadful side effects of alternative-energy technologies? These perspectives will launch us into the next chapter and subsequently lead us to some concluding thoughts and questions.

Chapter 8: Discussion and concluding thoughts[8]

Fascinating peculiarities emerge from viewing renewable energy as a belief system, which might otherwise go unnoticed without an analysis that incorporates both the material and the semiotic, knowledge and non-knowledge. This dissertation has endeavored to uncover instances of incongruence between semiotic valence and material observation in the development of energy technologies. And through those incongruencies it has explored the roles of various forms of non-knowledge in the maintenance of these incongruencies as a part of the innovative process. We have considered how the current geopolitical prioritization of renewable energy technologies is a phenomenon that may not be adequately explained through perceived technical benefits alone. The sociological integration of these attributes such as what Callon (2007) and other theorists have termed "market devices," technologies that define their own terms of commercial exchange through the knowledge and practices that surround them, leaves an opening for analysis. This dissertation reflects upon how we might more deeply explore architectures of non-knowledge and non-knowledge transfer, specifically through symbolic relationships, in order to gain a better understanding of scientific claims about, and prioritization of, renewable energy innovation.

8.1 Semiotic hegemony

Knowledge is power but so too is its absence. Initially, this work asked in what ways do forms of non-knowledge - such as strategic ignorance, trained incapacity, misdirection, and denial – contribute toward binding together potentially incommensurate systems of belief about renewable energy and ultimately the sustainability of modern human civilization? This ended up being too large of a question to bite into all at once. Still, aiming for this larger question allowed for an analysis of some particular cases, exemplified in chapters 4-7, in a fashion that might not have been possible without a large organizing umbrella. Still, a limitation of this approach has turned out to be somewhat disjointed accounts of non-knowledge, arising only

[8] Portions of this chapter published in "Conjuring clean energy" (Zehner, 2014)

momentarily in the chapters. I will propose some provisional concluding thoughts here to tie them together.

This research proposes that it is unsatisfactory to simply deliberate on how media, political, and scientific evaluations of ostensibly clean energy technologies are impacted by oversights, public relations framing, and overt negligence, which are already an acknowledged component of numerous technological development narratives. In such cases, the presence of non-knowledge is typically positioned either as countervailing force that subverts innovation or, in a similar capacity, as a gaping hole in a knowledge framework waiting to be filled – a destabilizing element to motivate the push for new innovative knowledge (Firestein, 2012). However, we have seen here that these characterizations do not fully flesh out various forms of ignorance that are not only integral to the innovative process but also, in the case of green technologies, can be central resources imperative to mobilize promotion, financing, implementation, and other necessities of green tech innovation. These observations, combined with a semiotic analysis, indicate that clean energy innovation may constitute a seductive anticipatory epistemology that draws from a cultured ecology of ignorance, which manifests consciously, unconsciously, or through some combination thereof.

The cases explored in this research expose a potential hegemony unchallenged - a calcified semiotic framework buttressed in part by the rhetoric of non-knowledge, evident in journalistic and scientific discourse. This research has proposed to challenge this apparent hegemony, not through the politics of bringing new facts to bear, but by attempting to balance this dialectic engagement through identifying unasked questions and unexamined assumptions.

Latour's (2004) hypothesis that "the ecology movements have sought to position themselves on the political chessboard without redrawing its squares, without redefining the rules of the game, without redesigning the pawns" (p. 5), aligns well with this interrogation of renewable energy innovation as something much different than revolutionary. We might just as easily see green tech as more of the same. The ingredients of a solar cell, for instance, arise from a list of some of the most toxic and destructive industrial practices ever deployed by humanity. That the especially complex practice of natural material extraction and refinement for solar cell manufacturing, drawing together expertise from nearly every realm of industrial civilization accumulated over generations, is associated with simple and independent off-the-grid living might alternately be understood as especially revealing about our capacity for self-deception. From an anthropological perspective Gell (1988) identifies a similar incongruence between material inputs, outputs, and consequences as defining quality of magic, which is costless "in terms of the kind of drudgery, hazards, and investments that actual technical activity inevitably requires. Production 'by magic' is production minus the disadvantageous side-effects, such as struggle, effort, etc." (Gell, 1988, p. 9). This stance is subsequently positioned by Elish and Boyd (2018) as not only providing an alternate regime of causal relationships but also minimizing attention to required methods and natural materials necessary to elicit the technical effect. Elish (2018) sums this up: "Magic denies an accounting of what went into making something work, or that it required work at all." In a similar vein of inquiry, this dissertation has not fully fleshed or evaluated the ostensible purposes and effects of renewable energy technologies but instead has focused on what purposes and effects they may obscure.

One position I have taken in this dissertation is to not assume the utility of purported renewable energy systems such as biomass (Chapter 1), electric vehicles (Chapter 4), hydrogen (Chapter 5), solar cells (Chapters 2&6), and wind turbines (Chapter 7) as necessarily solutions or even partial solutions to the challenges that the living world faces. In fact, we have considered that wind turbines and solar cells *in situ* may even represent net-energy sinks, rather than net-energy production. This research shows no *a priori* basis on which to presume the fidelity of green technologies and reveals that field data on their use, in numerous cases, similarly fails to provide such unilateral assurance. This research has instead contemplated the world of renewable energy as a belief system, one shaped by many social, psychological, and material factors. Further, this work has questioned whether this belief system could be understood as an act of denial about both the material conditions of the time we occupy on this planet as a species and our role in that period, a consideration we will take up in the latter part of this chapter. As a part of that analysis, I have drawn upon a sort of material semiotic approach to understanding specific and limited internal contradictions within this belief system, which no doubt have very real and tangible effects on lived experience.

The balance to hegemony is a hegemonic struggle, as Fairclough (2014) sees it, a dialectical engagement between discourse and other elements of social practices. I would largely agree with the appropriateness of this frame in principle, although I would point out that there are two outcomes of a struggle, one of which would not ultimately offer 'balance' to hegemony – that is, a hegemonic struggle could serve to reinforce the hegemonic semiotic regime itself, as theorized through the concept of a technological zombie in Chapter 5. In one sense this corresponds with Gramsci's (1995) claim that there is no place outside hegemony and that hegemonic systems are replaced by other hegemonic systems. In another sense, we may also consider how struggle might become a locus of reification, self-reinforcing rhetorical processes exemplified by, for instance, an echo chamber. Stones (2015) writes about a moment of subjectivity during which situated actors are involved in processing and responding to their own interpretation of an objective context (e.g. networks, pressures, and dynamics) wherein "actions may be rationally calculated, emotionally detached, consciously aware and decisive, or they may be devoid of rational calculation, fueled by emotion, completely intuitive, and hesitant" (p. 61). Stones continues, "their actions may be driven more by their perception of immediate external powers, forces and constraints or, alternatively, by the more enduring aspects of who they are as an individual, or as a collective actor, including their values, ethical orientations and principles, both personal and professional. Such identities include a sense of their own history and integrity, and their loyalties, commitments, tastes, ambitions, ideals, virtues and so on" (p. 61). Stones' characterization of the subject may come close to the sort of subjectivity that we might expect to see within the professions of journalists and scientists involved directly in the development of the energy technologies covered in the preceding chapters. Although, this work has leaned toward semiotic and rhetorical understandings of energy technologies more than psychological ones; we have come to the threshold of envisioning such psychological attributes such as cognitive dissonance and self deceit together with the social semiotic sphere surrounding energy technologies. For instance, ecologists, biologists and other natural scientists may consider it common knowledge that there is no waste in nature – outputs become inputs. Yet, humans seem adept at investing in dissonant definitions, especially when there is a perception of self preservation or some other measure of relative success within reach. Numerous multi-billion-dollar industrial research programs and in fact entire academic departments dedicate themselves to finding ways of capitalizing on nature's "waste" for human benefit through utilizing concepts such as "forest waste," "agricultural waste," "forest residue" and subsequent projects such as "forest management," "waste-to-energy power plants" and eventually more sophisticated euphemisms such as "working timberlands." There is no need to thoroughly interrogate these conceptions for potential internal dissonance, for these conceptual undertakings are admittedly premised on a metaphor of "waste" that practitioners themselves might readily identify as transparently illegitimate *a priori* when pressed.

In further support of this sort of broadening, Fairclough (2014) points to enactments that are in part "discoursal/semiotic" (p. 208) wherein "discourses become enacted as genres," (p. 209) a performance that this work has indicated may very well be necessary in order to build not just the political enactments but also the physical enactments of infrastructure of technologies characterized as renewable energy. As an extension I raise a question: are we witnessing, to some indiscernible extent, a collective self-deceit that may be existentially serving? If the fossil fuel epoch is seen as coming to a close then might it be easier to grapple with new extractive technological stories than to grapple with the eventualities of a world without fossil fuel?

In Chapters 4 and 5 we explored how technological zombies and electric car epistemologies expose differentiations between these performances and those of outright hoaxes. Walsh (2006), introduces her history of scientific hoaxes with curiosity: "I wanted to know how the hoaxes had managed to change, however briefly, the world views of their readers. I also wanted to see what the hoaxes could tell me about the negotiation of the scientific truth as a public commodity in America" (p. 2). The examples explored in this work share some identifying features of hoaxes, most significantly that they are susceptible to relatively straightforward material, physical, and thermodynamic challenges – much like an alleged perpetual motion machine might be debunked. This research has considered how a variety of experts, investors, academics, and journalists mobilize, negotiate, and report scientific truths in supporting structures of belief about clean energy technologies, including electric and hydrogen vehicles. While the negotiation of facts can be organized into phenomena we might identify as intentional deceptions or lies, might it be more interesting to follow the development of *unintentional dissembling* among groups of formally uncoordinated interests? Walsh (2006) identifies that "Hoaxes operate at the nexus of scientific and literary epistemologies" and they "adopt the rhetoric of popular media to criticize the specialized rhetoric of groups viewed as politically threatening" (p. 4). In contrast to most accounts of hoaxes, however, the cases presented in this work do not appear to contain independent or even aware hoaxers but rather groups of people acting within a particular form of reflexive subjectivity, whereby the potential exists for a scientific genre to percolate largely insulated from critique and to even advance technological industrialization.

This dissertation was not designed to research hoaxes or frame renewable energy technologies as such but has rather entertained if and how a framework of non-knowledge, whether strategic, trained, or otherwise accrued, could create rhetorical shelter for unwitting forms of group deception and uncoordinated dissembling. With a straightforward hoax, there is a hierarchy - those who "fall for" the hoax and those who "get" that the observed phenomenon is in some capacity manufactured. In introducing a reflexive framework of non-knowledge, these perspectives can merge into one. Non-knowledge need not be envisioned in hierarchical structures but it can function throughout flows of power involved in a sort of co-evolution as witnessed throughout the preceding case manuscripts. For instance, the political prioritization of solar cell, wind turbine and hydrogen vehicle technologies in Chapters 5-7 evolved along with specific non-knowledge about the material deployment of these technologies. Such knowledge may have destabilized the anticipatory knowledge regime and therefore the maintenance of a separation from that knowledge can carry distinct benefits for innovative work. Grin (2012) identifies strategic agency as a force that "co-shapes the transformation of the incumbent regime and the creation of novel regime elements" while also attending to the ways that subsequent agency can then draw upon the thus changed regime (p. 38). This work has explored precisely this conception of co-shaping within and through regimes of non-knowledge. For solar cells, political prioritization of the technology involved the exclusion of the largest database of experience-based knowledge about solar cell deployment. In the case of wind turbine and solar thermal systems, this co-shaping incorporated valuable ignorance about collected data to create and opportunity for more flattering data sets to enter in to the decision-making process.

Hecht (2012) writes on the invisibility of nuclear risks to workers in the African industry and in turn invisibility of the workers themselves. Hecht argues that the invisibility of risk and those affected did not necessarily arise from some deliberate strategy; "as data sets circulated through international conferences, committees, and publications, they acquired heft, making exclusion progressively more difficult to notice, and inclusion progressively more difficult to achieve," writes Hecht. "Reducing radiation risks could remain an abstract matter of principle, the objective result of cost-benefit calculation, as long as African workers remained invisible." We might consider energy technology epistemes as collective and coproduced within a genre of storytelling, centrally informed through moments of amnesia about risks and impacts that are materially or temporally displaced. This research has extended to consider potential roles of non-knowledge reflexively co-evolving in the maintenance of hegemonic regimes through the examples explored in chapters 4-7. For example, many of the world's most influential scientists, environmental leaders, and policy makers consider solar cells to be a zero carbon energy production mechanism, yet one could just as easily consider solar cells to be just the opposite: a locus for the largest and most extreme extraction of finite and toxic materials on a per-kwh basis ever attempted. Professional use of the term "renewable energy" as a blanket stratagem of issue formation leads to a form of trained ignorance. We say "use renewable energy" instead of saying "dig up the earth, mine, dump the tailings, heat with coal, add heavy metals, add chemicals, and refine" or "burn the biology of the planet including animals, trees, plants, and seeds mostly grown with petrochemicals" – a process which few if any environmentalists would claim is renewable. This example shows how language can serve as a kind of structural linguistic ignorance, as Richard Feynman implied in a 1966 lecture on how to identify pseudoscience;

"There is a difference between the name of the thing and what goes on" (Feynman, 1969).

Scientists could rhetorically place solar cells, electric cars, and wind turbines in with the assemblage of practices such as tar sands extraction, natural gas fracking, or mountaintop removal for coal. But they don't. Why not? High-tech energy devices may be themselves fascinating. However, many of their constituent materials are not - aluminum, steel, glass, and concrete for starters. Consider, for instance, how we all recognize that our cell phones contain heavy metals, rare earth elements, and conflict minerals such as cobalt. We don't consider our cell phones to be green at all. But imagine covering your roof in cell phone materials. Or, driving to work in a machine that contains roughly a thousand times as much of such elements. We call these practices clean, and so do the vast majority of politicians, businesses, and mainstream environmental groups around the world.

Figure 8.1: Comparing embodied cobalt in dirty- and clean-technologies. Data from: Frankel, 2016

In the cases presented in this work, technologies such as solar cells and electric cars are seen as something separate from the industrial practices from which they arise and which they aspire, implicitly, to sustain. As introduced earlier, Schwarz-Cowan (1983) relatedly shows how housework has been imagined as somehow apart from industrialization and organized capital markets. Schwarz-Cowan challenges the prevalent assumption of researchers, many from within a Marxist frame, that housework "is the last dying gasp of feudalism … the last surviving indicator of what the Western world was like before the market economy reared its ugly head" (p. 5). Here too, we see a parallel with techniques classified as green technologies. These technologies are frequently associated with a back-to-the-basics sort of bucolic imaginary. This imaginary is characteristic of much environmental literature on homesteading, preppers, living off the grid, and sustainable living, all framed in opposition to modern capital markets, an analysis adopted most notably in the popular work of Klein (2014). However, energy technologies such as solar cells and wind turbines might alternately be imagined at the pinnacle of market-driven capitalism, given that their material lives necessitate exceptionally capital intensive processes, highly specialized divisions of labor, and global economies of scale covering everything from the mining of rare earths to the hiring people with doctorates in material science and the complex systems of expertise required to pull them all together (Capellán-Pérez, et al, 2019; Orr, 1992; Gibbs, 2020; Kim and Karpinski, 2020). During his research on solar PV implementation, Roos (2021) discovered that however decentralized solar cells may have appeared in the literature, "when installed on rooftops and balconies, is not a local affair at all…The problem was that the vision for an environmentally sustainable and democratically aligned solar-powered energy regime orchestrated by grassroots actors was founded upon what seemed to be a socially and environmentally dubious division of labor in the world economy. To keep prices on solar panels low enough to be politically subversive appeared to require that they be produced on the other side of the world at low wages, with low environmental regulations, and often in fossil-powered industries… This means that the political visions for a solar powered future may not be consistent with the reality of their practical implementation." As Schwarz-Cowan observes, "to get our bread to the table, we still need bakers, agribusiness, utility companies, and stove manufacturers" (p. 6). The strong symbolic association between rooftop solar cells and a bucolic sustainable lifestyle independent from fossil fuels and capitalist enterprise, makes it difficult to speak about the observed material characteristics and capitalist tendencies of solar power without, as Cohen says, "confusing our listeners" (p.211). And that discordance is not always a hindrance, as we have seen in the preceding case manuscripts. If appropriately firewalled, discordant belief can become a resource to draw upon for the advancement of technology enthusiasm, prioritization, and funding.

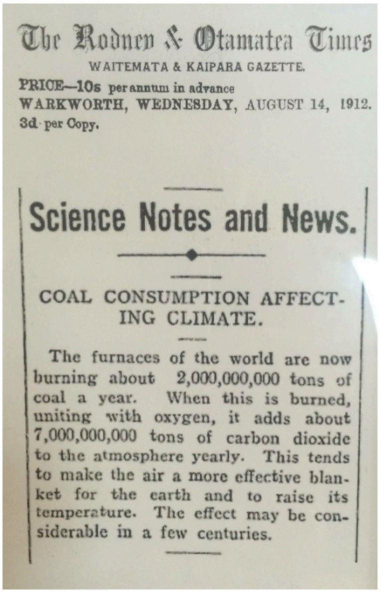
8.2 Roles for ignorance and materiality in climate issue formation

The storytelling of the IPCC, The Royal Society, and the Solutions Project, and indeed the storytelling of all mainstream environmental groups, now centers on the existential threat of climate change, global warming, or growing levels of carbon dioxide in the atmosphere and the support for energy technologies as a solution in whole or part. The story of "climate-speak," for lack of a better term, has multiple effects. One, the purported effect, is to alert humanity to threats posed by physical planetary changes due to growing levels of carbon dioxide in the earth's atmosphere. This goal is not in question here. But another effect, one of particular interest here, is how climate-speak can also act as surrogate to replace the need to grapple with an unsavory problem underlying climate change itself, human expansionism, including mining, biodiversity impacts, habitat destruction, land use changes, agriculture, and the thermodynamic observation there are too many humans consuming too much (at an exponentially increasing scale and unequally) for a finite living planet to endure (Fischer-Kowalski, 2014; Maxwell, Fuller, Brooks, & Watson, 2016; Seibert, 2020; Shragg, 2015).

In the early 20th century, Lippmann (1922; 1927) wrote that the increasing complexity of technological questions required not direct public engagement but rather democratic representation through experts. Dewey (1927), on the other hand, saw a straightforward role for the public to be involved in decision-making about technological questions as part of a democratic society that he imagined in egalitarian terms. Furthermore, Dewey's inclusion of materiality within his discursive and semiotic analyses is relevant here. As Brown (2009) aptly sums up, "Dewey believed that conversational constraints become intelligible only in the context of material constraints. These constraints are 'the world' and they are not lost" (p. 136). For instance, Dewey (1927) pointed to the potential for harmful "consequences of action" on third parties for which decision-making experts would be ill-equipped to engage. There are certainly limits to Dewey's broader analysis from a contemporary social science perspective, principally the framing of the state as a unitary entity, rather than a globally influenced one, and proposed objective definitions of public affairs (Marres, 2007). But Dewey and Lippmann outline a move to conceive of public involvement as not simply a passive expression of "public will" but a more active engagement with issue formation that involves direct, for Dewey, or indirect, for Lippmann, democratization of scientific and technical knowledge. This dissertation extends to open a potential role for instrumental ignorance and other forms of non-knowledge in the practice of issue formation. Indeed this was anticipated by Dewey a century ago. Take for instance how Dewey's (1927) appeal for direct public engagement in technical decision-making is presumably informed, in part, through a phenomenon he identified as "occupational psychosis," essentially the normalization of certain concepts or actions within a close knit group of people, which might seem absurd to those outside the group. We might view this as a dichotomization between the conceptual frames used by a certain group of experts in opposition to general understandings shared by a greater public. Specifically, this dissertation has sought to explore what happens if such a psychosis encompasses both experts and the public, either in part or entirety, into a sort of encumbering worldview.

Latour (2004) argues that "at no time in its short history has political ecology ever had anything to do with nature, with its defense or protection" (p. 5). He continues, "it claims to protect nature and shelter it from mankind, but in every case this amounts to including humans increasingly, bringing them in more and more often, in a finer, more intimate fashion, and with a still more invasive scientific apparatus" (p. 20). Latour's main thesis extends to argue that the belief that political ecology is foundationally inculcated in nature is itself an illusion leading to impotency, preventing the environmental field from understanding its own practice. The utterance of climate change acts as a lingua franca across broad global constituencies for challenges involving ecosystems, pollution, biodiversity, limits, inequality, and other issues of concern to the majority of people with what we might call progressive sensibilities. In fact, it is difficult to find any issue of concern over recent decades that some journalist or activist group hasn't attempted to rhetorically funnel into the problem of climate change.

Figure 8.2: A clipping about anthropogenic climate change from a New Zeeland newspaper in August of 1912



The Rodney & Otamatea Times

WAITEMATA & KAIPARA GAZETTE.

PRICE—10s per annum in advance

WARKWORTH, WEDNESDAY, AUGUST 14, 1912.

3d per Copy.

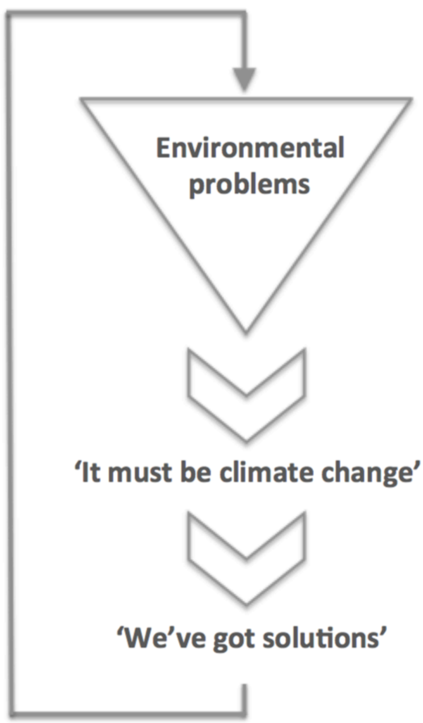
Science Notes and News.

COAL CONSUMPTION AFFECTING CLIMATE.

The furnaces of the world are now burning about 2,000,000,000 tons of coal a year. When this is burned, uniting with oxygen, it adds about 7,000,000,000 tons of carbon dioxide to the atmosphere yearly. This tends to make the air a more effective blanket for the earth and to raise its temperature. The effect may be considerable in a few centuries.

The century-old observation that climate change is occurring and likely anthropogenic is not in itself a matter of interest for this work. What is relevant here, in situating the broader relevance of this work, is the semiotic charge induced within 1) a context of political productivism (Zehner, 2012; Graetz, 2013), 2) an increasingly industrial and commercial style of scientific inquiry in universities and private enterprise (Kwa, 2011), 3) an environmental movement funded through the titans of industry and banking (Dowie, 1995, 2001; US Senate, Committee on Environment and Public Works, 2014), 4) a fourth estate imbued with productivist inclinations as surveyed in the third chapter, and 5) a receptive public, in which the translation of these various languages of concern manifest specifically into what I identified earlier as "climate-speak." These issues of concern become translated immediately, and in many ways automatically, into technical and economic solutionism such as carbon trading schemes, energy technologies, electric vehicle subsidies, and the like. When deployed, these solutions can do nothing to address the underlying dominance, through agriculture, aquaculture, logging, mining, and other activities of humans over other life on this finite planet (see Capellán-Pérez, et al, 2019). In fact, the reliance on natural material extraction endogenous to technical solutions would stand to make all of the original issues of concern, including climate change, more pronounced (Maxwell, Fuller, Brooks, & Watson, 2016). It is not clear how to even compare qualitative differences in human consumptive impact. For instance, a small number of early humans who were living quite modestly by today's standards have been implicated in squeezing out mammoths and numerous other megafauna (Ceballos, 2015). This is essentially a story of death-by-a-thousand-cuts with humans historically consuming biomass for food, energy, and shelter. What is more destructive? 1) a group of humans digging up and burning the *dead world* of fossil energy, or 2) a group of humans killing and burning the *living world* of bioenergy? This is a largely unexplored question that would carry implications for capitalist critiques that rely on the imaginary of local living and local energy grids separate from capital controls as a defining characteristic of democratic environmental equity.

Figure 8.3: Environmental problems yield climate solutions that yield more environmental problems



Many of the material dynamics we have reviewed, such as the birth of solar cells enabled through coal, could evoke anxiety about natural material extraction limitations and, in turn, modern living, of which green technologies are a constitutive force (see *Dwell Magazine*, any issue). Earlier we considered whether technological romanticism may help us avoid considering a potentially uncomfortable reckoning with the depletion of requisite natural materials and their eventual scarcity – a comfortable way of denying that expansion of our collective human presence must eventually come to an end. Consider additionally terror management theory, which in part holds that when people are reminded of their eventual mortality they tend to grasp on to preconceived worldviews and convenient symbols (Greenberg, Pyszczynski, & Solomon, 1986; Becker, 1973). In a sense, it is precisely during times of energy distress when we might expect to see the most value in grasping on to techno-optimistic symbols that promise to maintain familiar systems of expansion based on energy production. And it follows that we might consider the role of this symbolism as a motivator toward an analysis of ecological modernization more broadly. For instance, as statements about climate change from the IPCC have become more urgent, so too have scientists' patronage of solar cells and other productivist technologies, which, incidentally, they believe will preserve "economic growth" (IPCC, 2014; Geels, Sovacool, Schwanen & Sorrell, 2017).

Productivist narratives may also defend against challenges to our consumptive belief systems, allowing us, as energy users, to see our actions as just and desirable (Jost & Hunyady, 2003). Cognitive dissonance theory holds just this. To the extent that behavior and beliefs conflict, it is easier to adjust or defend one's belief about a subject (e.g., solar cells replace coal use) than to modify a behavior (e.g., reducing consumption), particularly if that behavior is associated with our impending mortality (see Festinger, 1962; Jonas, Greenberg, & Frey, 2003).

An effect of these self-reinforcing feedback loops might be understood as a form of collective denial that is egotistically self serving. Climate-speak is a language that in effect presumes, "We aren't the problem; climate change is the problem; we have the solutions." In a similar fashion to the way to Becker (1973) characterizes human civilization as a semiotic defense mechanism against reckoning with our own mortality, we may see climate-speak as a defense mechanism against contemplating our capacity for ecological- and self-destruction. Clean energy isn't just a comforting story we tell ourselves. It is a comforting story we tell ourselves *about ourselves*. (a play on Geertz, 1973 definition of culture)

8.3 Productivist ethos in media and beyond

The first organizing research question for this work was to ask what, if any, symbolic dispositions of energy technologies are emanant in the public realm surrounding sustainability and in what ways do these appear to come into alignment or discordance with the measured or otherwise observed experience of these technologies *in situ*? In Chapter 3, I asked what symbolic inclinations might we be able to identify in energy technology discourse? And, if we accept that cultural conceptions of energy play a central role in the co-construction of the built energy infrastructure, then could a culture of productivism be situated as an underlying force to assess structures of non-knowledge in political, business, institutional, and scientific discourse, which researchers can draw upon as a form of green capital?

This dissertation has been able to explore this question, but only within a limited scope, in our case energy journalism, and then also within a limited timeframe. When faced with readers who were anxious about fossil fuel security during the oil price shock leading up to the 2008 global economic crisis, this work indicates that public science writers overwhelmingly focused their journalism on energy production strategies rather than energy reduction strategies. They covered these productivist solutions with character-driven narratives. They analyzed these technologies in terms of future expectations rather than present states. And, they framed energy production as a solution to the anxieties at hand: energy independence and climate change.

Throughout, I have highlighted media representations of solar cells as a promising "zero carbon" energy source that will "inexpensively" lead to "energy independence" through "future" technological advancements. We have witnessed a distinct discordance between media renderings of alternative energy and material observations on the ground. But this is not entirely surprising. Media representations of alternative energy are not methodical surveys and analyses of data and thermodynamic laws. They are the product of a much different type of process that values objectivity, balance of opinions, and rhetorical dichotomies such as comparing alternative-energy technologies to fossil fuels, thus reinforcing the impressions that their qualities are comparable or that increasing alternative-energy flows will correspondingly decrease fossil fuel consumption, an assumption for which evidence is lacking (York 2012; 2016; Zehner, 2012; 2013). The high cost of investigative work has pushed journalists to use videos, photographs, and computer renderings developed by the interests that stand to benefit from various forms of strategic ignorance regarding background, contextual fundamentals, or the structural origins of increasing energy use. Numerous media outlets directly reprint special interest group content under their own mastheads. These include The Detroit Free Press, The New York Times, Alternet, Salon, Truthout, The Associated Press, Bloomberg, Business Week, The Weather Channel, The Guardian, Newsweek, The Atlantic, New Republic, Mother Jones, WIRED, Slate, MSNBC, and the McClatchy Group, a conglomerate of 30 daily newspapers across the United States. This pay-to-play special interest content arises from within a sphere of private, typically business, interests and readers have a difficult time distinguishing between such sponsored content and traditional independent journalism.

Figure 8.4: An image in The Guardian aptly captions the symbolic import that solar cells can offer to polluting industries, pointing out that solar cells can be "more powerful than a billboard." Incidentally, this image was not a product of traditional reporting, but a paid article by the industry in an apparent effort to signal its own green credentials to readers. Source: The Guardian and General Motors (2016)

Media representations of energy technologies such as solar cells, as romantic, promising, zero carbon, and leading to energy independence, follow from a historical valorization of alternative energy production as a solution, in whole or part, to the material, climate, and energy challenges that humanity faces. The politics of production are far more palatable than the politics of restraint, as U.S. President Jimmy Carter learned in the 1970s. After asking Americans to turn down their thermostats and put on sweaters, Carter received a boost in the polls. But voters ultimately turned to label him a pedantic president of limits. "No one has yet won an election in the United States by lecturing Americans about limits, even if common sense suggests such homilies may be overdue," remarks historian Simon Schama (2009, pp. 307-308). "Each time the United States has experienced an unaccustomed sense of claustrophobia, new versions of frontier reinvigoration have been sold to the electors as national tonic" (Schama, 2009, p. 308).

Clean energy is the tonic of choice for the discerning environmentalist. Over recent decades, flows of political power within America and other parts of the world began pooling around energy technologies deemed to be renewable. In the 1980s, the Brundtland Commission brought the idea of sustainable development into the spotlight. The commission sidestepped societal programs to instead underline technology as the central focus of sustainable development policy (World Commission on Environment and Development, 1987). Soon after, the United Nations developed a sustainable development action plan called Agenda 21, which charged technological development with alleviating harmful impacts of growth. As the new centerpiece of social policy, there was little debate around technology, other than how to implement it. This faith in the ability of technologies to deliver sustainable forms of development evolved during a period of public euphoria surrounding information technology, agricultural efficiency through petrochemicals, management technology, and genetic engineering.

Mainstream environmental organizations were eager to fill the pews of this newly energized church of technological sustainability, which they themselves had helped to consecrate. A 1991 World Resources Institute publication stated, "Technological change has contributed most to the expansion of wealth and productivity. Properly channeled, it could hold the key to environmental sustainability as well" (Heaton et al., 1991, pp. vii). During the 1980s and '90s, environmental organizations began to disengage from concerns about the earth's limits to growth opting instead for what they called "sustainable development." Their former enthusiasm for stringent government regulation waned as they expanded roles for "corporate responsibility," "voluntary restrictions," "triple-bottom-line accounting," and "closed-loop production systems," which purported to be good for the environment and good for profits. In 2002, the United Nations narrowed its assessments by stating that technological sustainability would require "little if any political and cultural negotiation about modern lifestyles, or about the global systems of production, information, and finance on which they rest" (United Nations, 1998). And by 2004, Australia Research Council Fellow Aidan Davison observed that "the instrumentalist representation of technologies as unquestioned loyal servants" had come to fully dominate sustainable development policy (Davison, 2004, p. 136). Limits-to-growth theories have encountered limits of their own as effective conceptual tools for change.

Yet this work invites us to question whether the mass exodus away from these guiding concepts and toward passionate narratives of technological solutionism might be hindering other ways of seeing the human predicament.

8.4 Crisis of the productivist ethos during contraction

Set against the backdrop of a clear blue sky, alternative-energy technologies shimmer with hope for a cleaner, better future. Alternative-energy technologies appear to be generating a small, yet enticing, impact on our energy system, making it easier for us to envision solar-powered transporters flying around gleaming spires of the future metropolis. Understandably, we like that. These visions are certainly more pleasant than imagining food shortages, land and animal decimation, economic disintegration, and conflict, which we might otherwise associate with declining natural material availability (Capellán-Pérez, De Castro, & Arto, 2017; Capellán-Pérez, I., De Castro, C., & González, L. J. M., 2019). The immediate problem, it seems, is not that we will run out of fossil fuel sources in the near future, but that the places we tap for these fuels – tar sands, deep seabeds, and wildlife preserves – will constitute a much dirtier, more risky, and far more volitile portfolio of fossil-fuel choices in the future. Certainly alternative energy technologies seem an alluring solution to this challenge. But while this is a pristine and alluring vision, might it also be a deadly positive illusion (Hornborg, Cederlöf, & Roos, 2019; Holbrook, 2016)? In closing, this section aims to situate the objectives of this work into the broader context of limits on a finite planet. At the start of the work I questioned whether fascination with alternative energy may serve as a form of techno-denial to avoid facing the uncertain but inevitable end of expansion of our human presence. Since we live on a finite planet, the system of ever-increasing expectations, translated into ever-increasing demand and resulting in again increased expectations, will someday come to an end. Whether that end is due to an intervention in the cycle that humanity plans and executes or a more unpredictable and perhaps cataclysmic end that comes unexpectedly in the night is a decision that may ultimately be made by the generations of people alive today. How might a better understanding of this predicament change the types of questions that various groups ask about energy?

As described in Chapter 1, this dissertation has sidestepped typical scientific assumptions that energy technologies such as solar cells are a contributing solution to climate change, or even that they yield net energy *in situ*. Instead, this work has investigated both the materiality borne through the practices of what is classified as renewable energy as well as the semiotic valences of these energy practices. In course, an objective of this work has been to uncover unasked questions and perhaps theoretically necessary questions needed in order to stake certain claims and make assumptions typically accepted about renewable energy and green tech solutions. A resulting academic objective has been to produce a collection of questions and material semiotic perspectives from which to ask better, and grounded, questions about energy technologies in situ, rather than succumb to potential cultural obfuscations (Schwarz-Cowan, 1983). In the beginning of this work, I proposed pursuing a material account of energy technologies to humbly follow various potential *episodes of discordance* between symbolic conceptions and observed material attributes principally through 1) comparing claims by renewable energy advocates against their own facts and figures, occasionally transformed through straightforward multiplication or division to form alternative perspectives, and relatedly, 2) elucidating internal contradictions within the renewable energy belief system *a priori*.

While alternative energy technologies may mean different things to different people, we have seen that the heartiness of these notions manages to sustain a common identity across various disciplines. This dissertation has documented how solar cells, wind turbines, electric cars, and the idea of a hydrogen economy might be seen as "boundary objects," described by Star and Griesemer (1989, p. 393) as concepts "both plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites." These objects of affection "have different meanings in different social worlds but their structure is common enough to more than one world to make them recognizable, a means of translation" (Star & Griesemer, 1989, p. 393). Beyond their manifest intended purpose of producing electrical power, various groups employ these symbolic technologies for their own varied purposes. For industry, green tech offers tax breaks, production opportunities, and good public relations.

And indeed, solar photovoltaic circuitry, electric car designs, and other productivist devices are patentable and commodifiable in a way that passive solar design and walkable neighborhoods are not. For academic and institutional researchers, alternative energy can attract recognition and grant money. Elected leaders stand to excite their constituencies with visions of a cleaner future. Advocating for alternative energy enables concerned citizens to feel responsible and successful in combating environmental challenges.

Van Lente and Rip (1998) use the example of Moore's law, the expectation that the number of transistors on a microchip will double every twenty-four months, as a self-fulfilling prophecy wherein social expectations guide and constrain action. They outline a progression of promise-to-requirement in which an *option* becomes a *promise,* which functions as a *requirement* to be achieved, and eventually a *necessity* for industry to support. In order to attract investment, solar cells and other energy technologies rely on promises that are in turn based on symbolic associations with other high tech fields. But, there is a fundamental difference between energy promises and those involving microelectronics, nanotechnology, and neuroscience. These non-energy promises may employ copious energy and raw materials and still be considered successful. Not so for energy technologies (Murphy & Hall, 2010). Solar cells, wind turbines, and other energy technologies are therefore a special case, because there is always a chance that we are witnessing a certain type of technological development, that of a perpetual motion machine – a deception – perhaps created intentionally, but more likely through some combination of technophilic hope, instrumental ignorance, manifest destiny, narrowed attention, and other interacting dynamics.

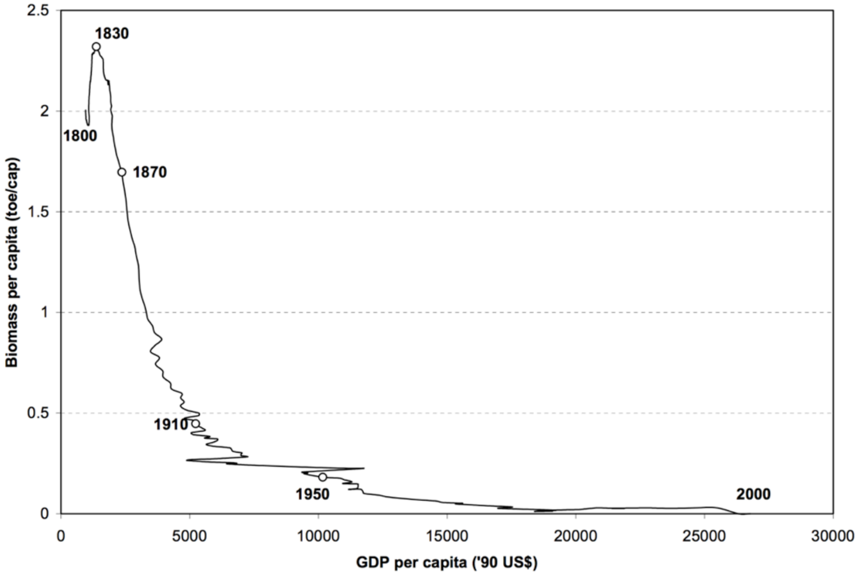
For instance, Bakker and van Lente (2010) also consider how hydrogen vehicle prototypes acted to communicate technological expectations to the greater public, therefore shaping technological trajectories. But, was the "hydrogen economy" a story of technological development or the performance of a technological illusion? In fact, we may be witnessing both. In the fourth chapter, we considered how the hydrogen dream arose from a complex alignment of interests, which I argued coalesced to synchronize a future narrative that featured selected benefits and diminished or overlooked associated side effects and limitations while allowing for luxurious imaginations about abundant clean transportation. Just because a technology has attracted broad scientific support and investment doesn't necessarily mean that it conforms to the laws of physics. Through expanding our social scientific analyses to engage the material characteristics of energy technologies, as slippery as those are, we stand to shed light on prospective perpetual motion machines standing among the lineup of productivist strategies, or at least identify some unasked questions.

The lens of economic contraction slices open some additional alternative energy assumptions, scarcely explored in public science and academic literature, for closer examination. To begin, do solar cells and wind turbines offset fossil fuel use? Do they produce net energy (Ferroni & Hopkirk, 2016)? As I stated previously, I do not intend to answer these questions here. Rather I intend to explore why you, I, and other researchers might do well to ask them. It is tempting to cite studies on carbon accounting, EROI, EROEI, lifecycle analyses, and the like to explore such questions. However, previously we considered how such studies generally valorize easily quantifiable factors while ignoring unquantifiable qualities such as energy density, storability, portability, fungibility, and transformability, as well as factors such as risks, tradeoffs, and labor requirements. These and many other considerations do matter, even though they do not fit neatly into the confines of a quantitative study (Tverberg, 2016; Zehner, 2013; Ferroni & Hopkirk, 2016). We may be well served to be open to the idea that the ubiquitous prevailing academic conceptions of energy return on investment for green technologies are subject to the workings of an echo chamber. Taibbi (2020) succinctly identifies that the academy in particular can, though its own confines, foster echo chambers; when "no one around you is disagreeing with you… you can see your theory everywhere and never have anybody disagree with it (6:00)." I present no solution to these methodological conundrums moving forward. But we may ask whether relying on this literature to make sense of the world is like trusting a team of food critics who judge meals using nothing but rulers.

If solar cells do offset fossil fuel and yield net energy, then regions facing economic hardship might presumably embrace them, as solar cells would be cheaper than the fossil fuels used for their construction and use. Modern solar and wind industries should thrive in such a context, but they have not. Why? Solar advocates complain about a lack of political will. But what does "political will" mean during an economic crisis when money and energy inputs are scarce? An alternate explanation might simply be that the price tag is too high. The high up-front cost of alternative energy technologies requires financing. And, financing currently relies on investor confidence and expectations for aggregate economic expansion. Will the economic constraints on solar deployment supersede material or technical limits (Hornborg, Cederlöf, & Roos, 2019; Weißbach, 2013)? Solar cells rely on an economy of finance and investment that faces instability without aggregate economic expansion. In this way, expensive "clean energy" technologies rely on the froth generated within an expanding economy that is itself driven by fossil fuel. (Brown et al., 2014; Ayers & Voudouris, 2014; Zehner, 2013). Considering these technologies within a context of economic decline starts to reveal why alternative energy expectations in Spain, Greece, and elsewhere unraveled and why the tightly wound conceptions of renewable energy are loosening in other countries where they have been most enthusiastically embraced, most notably Germany where "political will" hit turbulence and solar initiatives were mocked by political opponents and even some in the mainstream media as their markets degenerated (Boisvert, 2013; Premalatha et al., 2012; Palmer, 2014; Welke, 2014). Can solar cell industries operate in a contracting economy? The experiences during economic contraction in Greece and Spain, limited as they are, do not auger well (Prieto, 2013; Ayers & Voudouris, 2014).

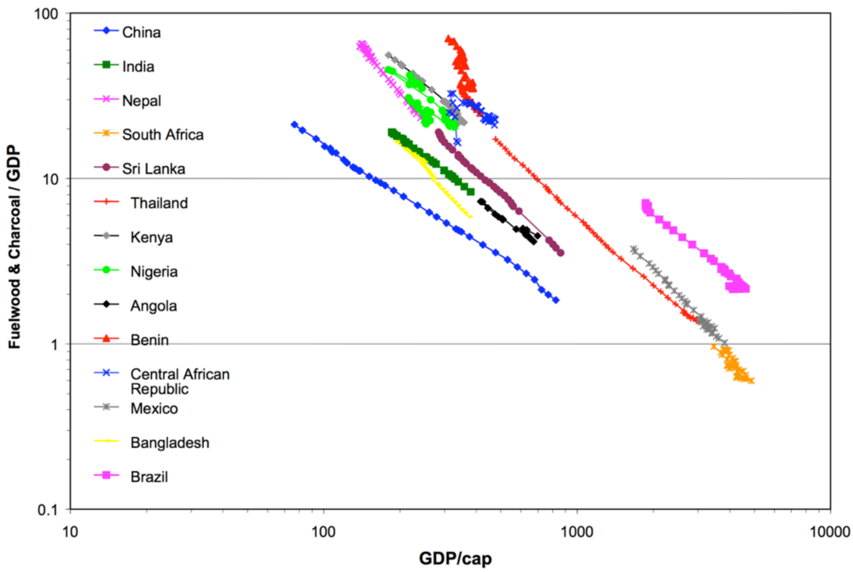
As introduced in the first chapter, the unaffordability of fossil fuels forced many Greeks to cut down trees for fuel during a period of economic collapse, stressing already greatly diminished forests that will not survive widespread cutting given the expansion of human presence in the region that fossil fuels have sustained (see Bologna & Aquino, 2020). Greece is not alone. Historically, as wealth and industrialization in the United States increased, biomass use decreased, as shown in Figure 8.5 (Victor, n.d.).

Figure 8.5: Biomass use in the United States decreased as wealth increased. (Chart courtesy of David Victor, used with permission)



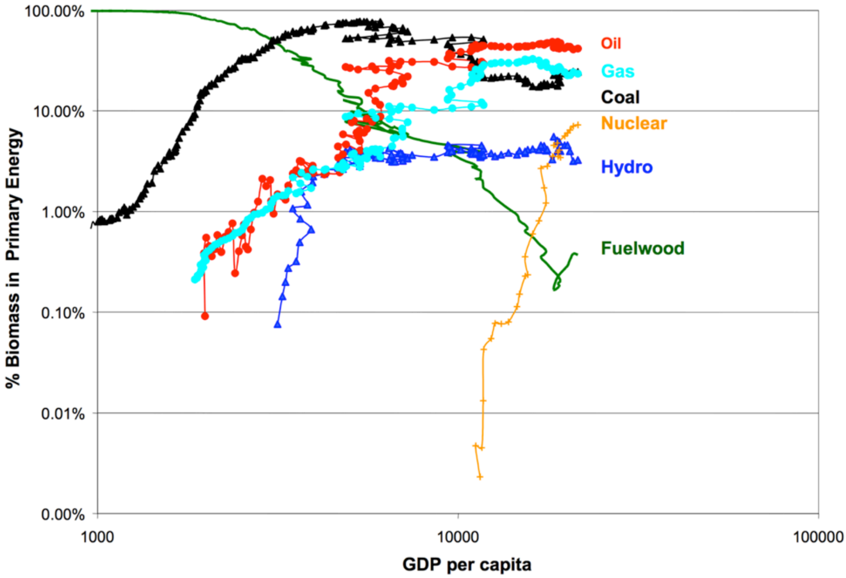
In fact, a number of nations have experienced a similar trend away from burning forests for fuel as GDP per capita increased over time as shown in Figure 8.6.

Figure 8.6: Biomass use in numerous countries decreases as wealth and access to fossil fuels increases. During periods of economic contraction, will biomass use go back up? (Chart courtesy of David Victor, used with permission)



This shift away from biomass energy has been filled by fossil fuels - oil, gas, and coal - as well as their derivatives, hydropower and nuclear (see Figure 8.7). Note here that dams and nuclear power facilities require fossil fuels for their construction, not just for raw energy but as a chemical deoxidizer for the production of materials such as concrete and steel. Nuclear facilities in particular also rely on fossil fuel in the form of expertise via universities, government labs, military infrastructure, complex systems of fabrication, and other contributory aspects which are all within a lineage that can be principally traced back to easy access to ample quantities of concentrated fossil fuel.

Figure 8.7: Biomass usage is replaced by fossil fuels and derivatives as incomes increase. (Chart courtesy of David Victor, used with permission)



The experience in Greece portends that this relationship also works in the reverse. As access to fossil fuels decreases, biomass use increases. This is remarkably problematic since fossil fuel use has enabled far greater human expansion (through not only access to fuel but also petrochemical fertilizers, drugs, and other products) than already fragile and depleted forests can replace (Hall, 2011; Neslen, 2016). It is in this sense that we might consider that hope can kill—and not just us. If history is any guide, we desperate humans may very well cut down the last tree and eat the last grub before our end.

We have no recent experience of significant and sustained global economic contraction by conventional understandings. But since expansionist ideals are well funded, politically powerful, connected with media, and pervasive in public thought, it is no surprise that most of us have come to accept many expansionist premises as self-evident truth (Dietz et al., 2012). We expect companies to increase their earnings, labor to expand, and material wealth to increase throughout the world until every last child is fed, clothed, educated, and prosperous. This story line is conceivable only if we are willing to believe that there are enough natural materials on the planet for an exponentially growing number of future inhabitants to consume, eat, play, and work at the standards that wealthy citizens enjoy today (Day, 2016). This belief is not possible given thermodynamic laws as we know them.

"The picture is as clear as it is disturbing," wrote International Energy Agency director Maria van der Hoeven after the global spurt in wind and solar development following the 2008 economic crisis, "the carbon intensity of the global energy supply has barely changed in 20 years, despite successful efforts in deploying renewable energy" (IEA, 2013b, p. 5). Nations spent $2 trillion on purportedly low carbon energy between 1990 and 2016 yet the power sector's carbon output *increased* 50% (IEA, 2013b; 2016). We can't say how carbon dioxide levels would have changed without that expenditure. But what might happen if nations spend another $2 trillion or perhaps $10 trillion on solar cells and wind turbines over the coming years? Is it even possible to spend that money without increasing natural material extraction (Vidal et al., 2013) and subsequently fossil fuel use? Alternative energy firms might say this expenditure is necessary to offset fossil fuel use into the future. But this assumed offset is not demonstrable *in situ* (York, 2012; 2016). James Hansen (2018), retired director of the NASA Goddard Institute for Space Studies, and one of the founders of the contemporary climate movement insists that "the notion that renewable energies and batteries alone will provide all needed energy is fantastical." He continues, proposing that "it is also a grotesque idea, because of the staggering environmental pollution from mining and material disposal, if all energy was derived from renewables and batteries.

Worse, tricking the public to accept the fantasy of 100 percent renewables means that, in reality, fossil fuels reign and climate change grows" (Hansen, 2018; see also Capellán-Pérez, et al, 2019). These high-level critiques from within the climate movement expose a disconnect between the promise of a renewable energy ideal and the lived experience of deploying energy technologies in an attempt to ward off climate change.

Qua (2011) identifies how science and technology have "tremendously enhanced our capacity to intervene in the natural and social worlds", yet cautions that ultimately "the idea that scientific progress has led to the constant expansion of our power over nature is a romantic myth" (p. 11). Instead, Qua argues that scientific progress, and in particular university science, is increasingly directed toward notions of utility defined within a neoliberal context with the roots in post war industrialization of science, science philanthropy sponsored by the captains of industry, Cold War rhetoric, and the belief that political leaders could use public policy to shape and guide a mission oriented science. Mitchell (2011) forms an account of how such democratic processes are intricately bound to carbon energy. And more specifically, Mitchell argues that this language of economic calculation found its place within in the technical uncertainties, from timing to impacts, of oil depletion and climate change. Where Mitchell concludes analysis, at attempts to develop alternatives to fossil fuels, we might at first be persuaded to see a parallel mode of coproduction informed through flows of energy political and scientific institutions but my research proposes an alternate frame. Solar cells, wind turbines, hydrogen reformation, and electric cars need not be seen as running parallel to carbon democracy but rather entirely within the same petro-neoliberal definitions of utility – more of the same by material measures, but this time dressed up in a semiotic achievement in its own right. Perhaps of some relevance here is Walter's (2012) observation that we humans "have evolved into a planning, agenda–making, dream–conjuring creature(s)." He makes the point that "we are the first survival machines to also become living, breathing imagination machines. If you compare us with other animals, our ability to create symbols turns out to be a kind of superpower, like being able to fly or peer through rock with X-ray eyes." Could our superpower also be our weakness? Are our clean tech plans no more than an alternate manifestation of our brains on fossil fuels?

In this work we have considered whether the system of belief – that solar and wind energy technologies offset fossil fuel use and decouple economic activity from natural material extraction – maintains itself through various forms of assumptive and applied ignorance and may even form the central and necessary underlying strata for valuing and prioritizing green tech innovation. Materially, in Chapter 7, this work introduced a potential boomerang effect, whereby energy production funding stands to expand energy supplies and ultimately lead to greater aggregate consumption (Zehner, 2012; Zehner, 2013c). Within an expansionist economy, even energy efficiency efforts open opportunities to grow overall energy production through various rebound effects (Herring et al., 2009; York, 2012; York, 2016). What plausible theoretical stance could explain how increasing energy production in an expanding economy would lead to lower natural material extraction, or for that matter, lower carbon emissions? We know that both energy production and reduction "solutions" have the perverse potential to further aggregate economic expansion and natural material extraction, presumably hoisting civilization toward an even steeper cliff. Perhaps we could expend our precious remaining fossil fuels to prepare for the coming contraction. But how? During a time of contraction, might the perceived value of low-tech energy reduction strategies (e.g. insulation, passive solar gain) increase? Meanwhile, what will become of pricey high-tech energy production schemes if they are indeed enabled by, and by-products of, fossil fuels, mining, and an expansionist economy? (see Capellán-Pérez, et al, 2019; Kim and Karpinski, 2020)

Guy Debord wrote that "the society which rests on modern industry is not accidentally or superficially spectacular, it is fundamentally spectaclist" (Debord, 1970, p. 14). Perhaps he could have spoken similarly about modern energy. Or, modern environmentalism. Debord's spectacle is a divine deity around which duty-bound citizens gravitate to chant objectives without reflecting upon fundamental goals. It is all too easy for us to miss the limitations of alternative energy, Debord might say, as we drop to our knees at the foot of the clean energy spectacle, gasping in rapture. This oracle delivers a ready-made creed of ideals and objectives that are convenient to recite and that bear the authority of science.

These handy notions of clean energy reflexively work into environmental discourse. And as we have seen here, productivist environmentalists can enroll media to tattoo wind, solar, and biofuels into the subcutaneous flesh of the environmental movement. In fact, these novelties come to define what it *means to be* an environmentalist. And environmentalists aren't the only ones lining up for ink.

Every news article, congressional committee hearing, textbook entry, and bumper sticker creates an occasion for the visibility of solar cells, wind power, and other productivist technologies. Throughout this analysis, we have additionally explored how renewable energy discourses in public science media, academia, and politics draw upon not only organized frameworks of knowledge, but also rhetorical genres of non-knowledge. Numerous actors draw upon both moments of visibility as well as invisibility to articulate paths these technologies ought to follow. First, diverse groups draw upon flexible clean-energy definitions and assumptive ignorance to attract support. Then they roughly sculpt energy options into more appealing promises – not through experimentation, but by planning, rehearsing, and staging strategic media demonstrations, a process that is itself a form of selective knowledge management. Next, lobbyists, foundations, and PR teams transfer the promises into compelling stories, legislative frameworks, and eventually necessities for engineers to pursue. Green tech innovative processes rely on structural ignorance to factors conveniently difficult to quantify, assumptive ignorance involving offsetting fossil fuel use or decoupling, strategic ignorance of recorded but mutable factors, consequential ignorance of material unintended effects that remain hidden, and other forms of non-knowledge that are valuable assets to actors and institutions involved in capitalizing on innovation. What happens to our analyses of innovation if we frame innovators as skilled, or perhaps unwitting, conjurers of illusion?

A consequence of alternative energy visibility-making appears to be the necessary invisibility of other options. There's only so much room on the stage. Energy reduction strategies, degrowth, economic contraction, and other descent pathways, can remind people of their reliance on finite natural materials, their own vulnerability to the imminent contraction, or perhaps even their mortality. In ominous times, might individuals invest their enthusiasm into alternative energy narratives, thereby allowing themselves to cognitively avoid existential threats and circumvent otherwise undesirable reckonings? Perhaps we have forged magnificent energy spectacles only to cast ourselves as climatic superheroes within the late stages of an illusion of abundance. If so, then these spectacles have come to protect us from questions about our own culpability in ecosystem decline. Green technologies seem to bypass worries of raw material scarcity since they exist in our minds apart from fossil fuel and extractive industry. We may invite them to ease our anxieties about increasing levels of CO_2 so long as we faithfully believe that they are carbon-free undertakings. But perhaps most centrally, clean energy spectacles protect us from considering our own aggregate growth, in consumption and numbers, which could not otherwise come to a peaceful end outside the storytelling of the current expansionist milieu.

Appendix: Ninety-one questions for students and researchers

With a few exceptions, humans have historically considered growth to be good, leading to more material wealth for more people – especially those clever enough to have been born into the right family (Graetz, 2013). But is the story of growth only conceivable within an illusion of endless abundance?

How, specifically, are green tech agendas crafted around selective knowledge about known consequences?

If wind and sunlight are free, why are wind and solar energy deployments so expensive, requiring billions in subsidies? Where do solar cell and wind turbine costs ultimately arise, if not from fossil fuels (via labor, materials, expertise, power conditioning, etc.)?

If solar photovoltaic power is less expensive in practice than fossil fuel power, as some proponents claim, then why don't energy firms abandon the more expensive fossil fuels? Are they making bad business choices, or is there more to the story? And, if solar and wind power are less expensive than fossil fuels in practice, then why would hundreds of billions of dollars be needed to subsidize their usage?

Since subsidies can clearly make solar costs, and subsequently energy inputs, appear far lower than they actually are, why do researchers and journalists typically leave subsidies out of their cost reporting, or otherwise neglect to tally a full accounting of them? Similarly, why are green tech material imports from abroad, with their embodied minerals, energy, labor, and ecological impacts, not treated as energy laundering?

How does the monetary cost of an industrial commodity correspond to the quantity of energy inputs used to pull it from the earth and process it into a usable form?

The story of renewable energy is powerful as an organizing principle of activism and capital but beyond the physical attributes of these technologies, what else does the story of renewable energy do for us on an intellectual and emotional level? How does it protect us? How does it shape our conceptions of ourselves as moral citizens? And, how does it influence the questions we even think to ask?

Does the genre of climate, sustainability, and energy abundance storytelling draw upon people's concern for our planet in the service of perversely intensifying its destruction?

Nations spent $2 trillion on purportedly low carbon energy between 1990 and 2016 yet the power sector's carbon output *increased* 50% (IEA, 2013b; 2016). We can't say how carbon dioxide levels would have changed without that expenditure. But what might happen if nations spend another $2 trillion or perhaps $10 trillion on solar cells and wind turbines over the coming years? Is it even possible to spend that money without increasing natural material extraction (Vidal et al., 2013) and subsequently fossil fuel use?

Despite their symbolic prominence in the clean energy movement, wind turbines and solar cells are not major components of what is globally counted as renewable energy, so why do environmental groups feature them as such?

Does this illusory aspect of the term "renewable energy," in which there is a disconnect between the referent and the referred, create a valuable disconnect between perception and reality? (see also Hornborg, Cederlöf, & Roos, 2019) Specifically, are tree-hugging activists advocating for renewable energy policies to principally cut and burn trees?

To what degree and in what ways do researchers succumb to unacknowledged emotional, cultural, financial, or technophile bias in crafting their alternative energy inquiries? To what degree and in what ways might researchers know that some representation isn't quite right but succumb to self-deception, positive thinking, or a prestige motive in order to craft various forms of ignorance in the service of valorizing what they know to be true and just (or profitable)?

If the fossil fuel epoch is seen as coming to a close then might it be easier to grapple with new extractive technological stories than to grapple with the eventualities of a world without fossil fuel? Are we witnessing, to some indiscernible extent, a collective self-deceit that may be existentially serving?

Scientists and researchers throughout many fields are generally in the business of finding ways to avoid technological failure and build upon technological success. Whether that success is truly a virtuous undertaking has been an open question for some time, and is of growing interest today given our precarious energy and economic predicaments (Ceballos, 2017; Gell, 1988; Kingsnorth, 2013; Mander, 1991; Tainter, 1988; White, 2009). What theoretical opportunities arise if we were not to immediately take these technological stratagems as part of a solution?

We typically associate aggregate growth with having more. But might one be able to propose just the opposite: that growth on a finite planet eventually leads to *less* for every individual? Less energy, less raw material, less ice cream? In these terms, wouldn't a decreasing presence of people over time with aggregate degrowth, leave a larger average reserve of natural materials for every human, as well as for other life? Where might such considerations lead our notions of equity? As long as the story of growth seems plausible to enough people, then growth may well continue. For a time. But to the extent that growth continues, might we view this as human civilization extending a gangplank out over a more abrupt decline, an ultimate form of Beck's (1992) "risk society?"

Our symbolic preconceptions of energy shape what options we consider as well as those we cannot see. Many of us hinge our civilization's future on the fundamental promise that innovations such as alternative energy will rescue us from potential ecological crises and fossil fuel shortfalls. Does this focus obscure other options? Furthermore, what risks might this system of belief create?

What, symbolic dispositions of energy technologies are emanant in the public realm involving sustainability and in what ways do these appear to come into alignment or discordance with the measured or otherwise observed experience of these technologies in practice?

In what ways do forms of non-knowledge - such as strategic ignorance, assumptions, trained incapacity, misdirection, and denial – contribute toward binding together otherwise incommensurate systems of belief about renewable energy and ultimately the sustainability of modern human civilization? Where is non-knowledge situated and how does it act within knowledge architectures?

If we accept that cultural conceptions of energy play a central role in the co-construction of the built energy infrastructure, then could a culture of productivism be situated as an underlying force to assess structures of non-knowledge in political, business, institutional, and scientific discourse? Can researchers, environmentalists, politicians and businesses draw upon non-knowledge as a form of green capital?

What can be learned from initiating a public and professional dialog that proposes a semiotic and material divide in green tech? What can be achieved through acknowledging a potential role for non-knowledge within green tech trajectories? How can such an analysis be structured and contextualized? What impacts might a consideration of non-knowledge have on the public understanding of energy technologies? Does this mode of analysis hold the potential to engage professional and lay audiences?

What have been the specific expected benefits associated with green technologies? And, how did these expectations map on to the measured material realities of these technologies once deployed? Finally, how does this relationship between expectation and practice form the questions we might choose to consider about green technologies?

Until power-conditioned solar and wind costs fall below the costs of fossil fuels they rely upon, might these technologies in effect represent fossil fuel consumption by alternate means? And, even if lower technology costs are achieved, then might they stimulate growth in the broader economy? In this case, might they also stimulate demand from economic sectors that are reliant on fossil fuels (Garrett, 2011)?

Might the performance of an equal comparison between power production strategies of varying qualities be necessary in order to craft the assumption that solar and wind technologies will offset fossil fuel use and therefore mitigate greenhouse gas emissions? Can the impression of an offset be maintained without such assumptive ignorance? Might we also characterize this as a type of necessary existential ignorance? That is, if wind and solar technologies do not ultimately offset fossil fuel use, then would the entire renewable energy project encounter an existential threat?

Does the innate complexity in tracing energy inputs of technologies open a space to eventually draw upon this non-knowledge as a resource for justifying innovative activity?

In an energy boomerang, subsidized energy induces a downward pressure on energy costs. Demand relatively expands, bringing the economy right back to where it started, with constrained supply coupled with sustained demand. That demand could manifest in electrical demand or through demand for products, services, and imports. Perhaps the harder we throw new power into the grid, the harder we risk demand coming back to hit us on the head? In an expanding economy, are larger solar arrays, taller wind turbines, and larger fields of biofuel crops just ways of throwing the boomerang harder?

How might the public understanding of energy technologies differ if journalists instead wrote about the energy technology industry's reliance on natural material extraction and fossil fuels for smelting and fabrication or how wind and solar arrays require conventional power plants to stand alongside them, or storage mechanisms such as batteries, which require further rounds of fossil fuel and material extraction?

Might large fossil fuel companies choose to produce solar cells in an attempt to be seen as "cleaner" and "greener?" The bigger the sin, the greater the need for atonement?

Might we question how politicians rely on the symbolic value of solar cells to boost their poll numbers in one hand while using the other to advance economic expansion, jobs, and extractive industries that feed solar lifecycles?

We have seen tension between the semiotic signifier and the signified, plausibly maintained through layers of non-knowledge, which may insulate symbolic impressions from the material attributes of energy technologies; might this manifest in more abstract structural forms as well?

Might the promise of solar cells act to prop up a productivist mentality more broadly, one that insists that humanity can simply generate more and more power to satisfy aggregate expansion?

The Sierra Club's evolved position on wind turbines is indicative of a shift in focus within the mainstream environmental movement - toward a notion that technologies such as wind turbines will mitigate climate change and related environmental threats posed by fossil-fuel power plants. One largely unaddressed question in the literature is what evidence undergirds this assumption? And, has it borne out in practice?

Turbines may not exhaust CO_2 directly but lifecycle calculations reveal that wind power technologies actually rely heavily on fossil fuels, which is why they are so expensive build, a consideration with ramifications we will revisit in the last chapter. In practice, does this leave so-called renewable wind power as a mere fossil-fuel hybrid? This spurs some further questions. First, if fossil-fuel and raw-material prices pull up turbine costs, to what degree can nations rely on wind power as a hedge against scarcity of their constituent natural materials? Moreover, where will the power come from to build the next generation of wind turbines as earlier ones retire from service? Will we simply have to fall back on fossil fuels?

Every energy-production technology carries its own yoke of drawbacks and limitations. However, might the allure of a magical silver bullet act to prop up and stabilize a system of extreme energy consumption and waste? If clean and abundant energy is just over the horizon, is there less motivation to clean up existing energy production or use energy more wisely?

Might subsidized wind turbines and solar cells, if they were to produce net energy, simply expand energy supplies and place downward pressure on prices? Might this in turn spur demand, entrench energy-intensive modes of living, and finally bring us right back to where we started: high demand and so-called insufficient supply? In short, do we risk creating an energy boomerang - the harder we throw more power into the grid, the harder the boomerang of demand will come back to hit us on the head? Are more efficient solar cells and taller wind turbines just ways of throwing the boomerang harder? If this were the case in the existing global expansionist context, increasing alternative-energy production might not displace fossil-fuel side effects but instead simply add more side effects to the mix. Instead of a world with just the dreadful side effects of fossil fuels, might we enter into a future world with the dreadful side effects of fossil fuel *plus* the dreadful side effects of alternative-energy technologies?

While the negotiation of facts can be organized into phenomena we might identify as intentional deceptions or lies, might it be more interesting to follow the development of *unintentional dissembling* among groups of formally uncoordinated interests?

What is more destructive? 1) a group of humans digging up and burning the *dead world* of fossil energy, or 2) a group of humans killing and burning the *living world* of bioenergy?

Since we live on a finite planet, the system of ever-increasing expectations, translated into ever-increasing demand and resulting in again increased expectations, will someday come to an end. Whether that end is due to an intervention in the cycle that humanity plans and executes or a more unpredictable and perhaps cataclysmic end that comes unexpectedly in the night is a decision that may ultimately be made by the generations of people alive today. How might a better understanding of this predicament change the types of questions that various groups ask about energy?

If solar cells do offset fossil fuel and yield net energy, then regions facing economic hardship might presumably embrace them, as solar cells would be cheaper than the fossil fuels used for their construction and use. Modern solar and wind industries should thrive in such a context, but they have not. Why? Solar advocates complain about a lack of political will. But what does "political will" mean during an economic crisis when money and energy inputs are scarce? An alternate explanation might simply be that the price tag is too high. The high up-front cost of alternative energy technologies requires financing. And, financing currently relies on investor confidence and expectations for aggregate economic expansion. Will the economic constraints on solar deployment supersede material or technical limits? Can solar cell industries operate in a contracting economy?

Walter's (2012) observes that we humans "have evolved into a planning, agenda–making, dream–conjuring creature(s)." He makes the point that "we are the first survival machines to also become living, breathing imagination machines. If you compare us with other animals, our ability to create symbols turns out to be a kind of superpower, like being able to fly or peer through rock with X-ray eyes." Could our superpower also be our weakness? Are our clean tech plans no more than an alternate manifestation of our brains on fossil fuels?

This work introduces a potential boomerang effect, whereby energy production funding stands to expand energy supplies and ultimately lead to greater aggregate consumption (Zehner, 2012; Zehner, 2013c). Within an expansionist economy, even energy efficiency efforts open opportunities to grow overall energy production through various rebound effects (Herring et al., 2009; York, 2012; York, 2016). What plausible theoretical stance could explain how increasing energy production in an expanding economy would lead to lower natural material extraction, or for that matter, lower carbon emissions?

We know that both energy production and reduction "solutions" have the perverse potential to further aggregate economic expansion and natural material extraction, presumably hoisting civilization toward an even steeper cliff. Perhaps we could expend our precious remaining fossil fuels to prepare for the coming contraction. But how?

During a time of contraction, might the perceived value of low-tech energy reduction strategies (e.g. insulation, passive solar gain) increase? Meanwhile, what will become of pricey high-tech energy production schemes if they are indeed enabled by, and by-products of, fossil fuels, mining, and an expansionist economy? (see Capellán-Pérez, et al, 2019; Kim and Karpinski, 2020)

Green tech innovative processes rely on structural ignorance to factors conveniently difficult to quantify, assumptive ignorance involving offsetting fossil fuel use or decoupling, strategic ignorance of recorded but mutable factors, consequential ignorance of material unintended effects that remain hidden, and other forms of non-knowledge that are valuable assets to actors and institutions involved in capitalizing on innovation. What happens to our analyses of innovation if we frame innovators as skilled, or perhaps unwitting, conjurers of illusion?

Energy reduction strategies, degrowth, economic contraction, and other descent pathways, can remind people of their reliance on finite natural materials, their own vulnerability to the imminent contraction, or perhaps even their mortality. In ominous times, might individuals invest their enthusiasm into alternative energy narratives, thereby allowing themselves to cognitively avoid existential threats and circumvent otherwise undesirable reckonings?

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