Energy Research & Social Science

Perspectives | STS & the Global Sociotechnical Transition

Renewing the Future: Imaginaries and Actualities of Global Energy Transition

I. Introduction

Since the publication of *Our Common Future* in 1987,[1] humankind has been called upon to contemplate its evolutionary journey as a collective enterprise oriented toward a distant future. That mission engages not only all of us as a species but it also seeks to bring our human selves into conversation – and responsible coexistence – with everything else upon the planet. Sustainability, a term that has dominated environmental discourse since the Brundtland Commission report, operates in this respect as a grand sociotechnical imaginary (STI). Following a widely accepted definition, sustainability can be seen as a "collectively held, institutionally stabilized, and publicly performed vision of desirable futures, animated by shared understandings of forms of social life and social order attainable through, and supportive of, advances in science and technology."[2] The embrace of sustainability as a universal mandate for humanity asks us to rethink, and reperform, all life as a movement toward a future that does not unjustly privilege the needs of the present at the expense of the needs of future generations. From its inception this normative aspect of the imaginary of sustainability has been coupled to technologically mediated transitions, above all in energy.

Confronting the looming disaster of climate change, the coupled imaginations of social change and technological change have merged into the vision of a zero carbon future, achieved through an energy transition that weans humanity away from its self-destructive dependence on fossil fuels. Not surprisingly, then, the concept of sociotechnical imaginaries has quickly caught on among social scientists examining aspects of that transition. It is tempting to look to STIs as an explanation for whatever seems to be working or not working in the domain of energy sustainability. Popularity, however, comes at a cost. In the interpretive social sciences, it is common for theoretical language to acquire force and precision through repeated use. How else do we understand such terms as *thick description* or *governmentality*, *ideal type* or *co-production*? But imprecise use can also dilute a concept, leading to loss of focus, and eventually a weakening of its analytic value.[3] Our aim is to resituate the term sociotechnical imaginary in energy research through a discussion of some of its recent uses, elaborated upon with our own empirical cases.

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[1] WCED, *Our Common Future*.

[2] S. Jasanoff & S.-H. Kim, Dreamscapes of Modernity: Sociotechnical Imaginaries and the Fabrication of Power, The University Chicago Press, Chicago, 2015, p. 4.

[3] Indeed, a reviewer of our abstract for this journal observed, "Make sure they also consider weaknesses to the imaginary approach or at least hedge attempts to problematize it." The comment is a little puzzling, since interpretive social science concepts cannot easily be classified as strong or weak. They illuminate, or do not illuminate, features of the social landscape that are otherwise undertheorized or obscure. They can of course be overused or inappropriately used, in which case they lose analytic power. Our article is offered as a prophylactic against such overextension of the STI framework.

We begin by problematizing some recurrent uses of the STI framing in prior contributions to this journal and to energy research more broadly. We first parse STIs along three dimensions that have attracted enough attention to generate theoretical confusion: the unit of analysis, or *scale* at which it makes sense to use the STI concept; the coexistence of multiple contested imaginaries, and the dynamics of *convergence* or *divergence* among them; and the role of *technology* in resolving contestation between imaginaries. Our analysis reveals a persistent tendency to use STIs as exogenous, independent variables, causally explaining why transitions do or do not occur, instead of as tools of interpretive analysis to illuminate how collective visions of desired and undesired futures take shape and solidify. We draw on these reflections to sharpen the analytic purchase offered by STIs, contrasting this interpretive lens with actor-network theory (ANT), another well-known STS framework. We then look at two exemplary cases of the energy transition in the global South centering, respectively, on the introduction of solar power in Senegal and India. In each case, we argue, a theoretically robust invocation of STIs allows us to display aspects of transition that remain obscured unless one stays attuned to the sense-making dimension of STIs.

Our substantive argument is that the STI of sustainability has fallen together, in the context of the energy transition, with an imaginary of what is renewable. Energy sustainability has become in short virtually synonymous with the mandate to switch to renewables. This identification of *sustainable* with *renewable* rests in turn on a privileging of the transition's material, technological dimensions over its sociopolitical ones, so that shifting away from carbon-emitting technologies to non-fossil fuels is accepted as a good in itself. Our analysis shows to the contrary that the move to renewables is not simply a matter of substituting one energy input for another. Rather, such a shift entails commitments to radical reconfigurations of human-nature relationships whose rightness tends to be taken for granted because the renewability of the fuel source serves as a metonym for the sustainability of the entire new assemblage. Our examples complicate that picture of smooth transitions from one energy regime to another by teasing apart the components of the imaginary of renewable energy. This analysis destabilizes the benevolent neutrality of the "energy transition," revealing modes of power and powerlessness at play in the elbowing out of one form of collective, energetic life by another.

II. Energy Research and Sociotechnical Imaginaries: The Variables Approach

Energy researchers have flocked to the concept of sociotechnical imaginaries to such an extent that Hess and Sovacool recently identified STIs as one of four major "groups of perspectives" in the ERSS literature.[4] They associate STIs with a strand of *cultural* thinking in energy research, one that focuses on imaginaries, fantasies and expectations to illuminate how "sociotechnical and material futures are imagined and strategically deployed."[5] In this section we review the growing

[4] D.J. Hess & B.K. Sovacool, Sociotechnical matters: Reviewing and integrating science and technology studies with energy social science, Energy Research & Social Science, 65 (2020), 101462.

[5] Hess & Sovacool, 7. They compare STI-based research with three other dominant strands: *policy analysis* approaches, which focus on the social construction and performativity of risk and economic modelling; *public participation* approaches, focusing on expert-lay relationships and the mobilization of publics; and *sociotechnical systems* approaches that look at the design of large-scale technological systems and politics of building and using, as well as actor-networks.

uses of STIs in ERSS to identify some salient theoretical confusions generated by this concept's widespread adoption.

We begin by bracketing off attempts to trace the term's origins to other social science work on "imaginaries," such as Benedict Anderson's "imagined communities" or Charles Taylor's work on "social imaginaries."[6,7] Claudia Strauss, for instance, highlights how anthropology came to speak of "imaginaries" rather than "cultural beliefs," and how "The Imaginary," was used to refer to a culture's ethos (as in the work of Cornelius Castoriadis) or latent fantasies (as in the work of Jacques Lacan).[8] Such disciplinary genealogies point to imaginaries as a term of art with wide resonance in the social sciences. Yet they also obscure the *independent* origin of STIs within science and technology studies (STS), where the concept does work that is far more relevant to problems in energy research.

Within STS, STIs direct attention to two specific dimensions of the more general phenomenon of co-production: the material and the temporal.[9] Jasanoff called attention to the interplay of these two elements in "Image and Imagination," her 2001 analysis of the Earthrise image as a "visual anchor … for emerging, globally articulated ethical concepts, such as the precautionary principle, sustainability, and intergenerational equity."[10] A by-product of Cold War tensions and the space race, the Earthrise image gave tangible form to an imaginary of planetary togetherness toward which the course of *a common* environmental future could be set. One could see in the emerging imaginary of "one Earth" a simultaneously epistemic, material and normative view that was collectively held, publicly performed and institutionally stabilized in multiple contexts: from Thai airline commercials to Disney's Epcot Center; in important policy documents such as WCED's *Our Common Future*; and in America's expanding view of its role in global environmental politics.

This account, which predates by almost a decade the formal introduction of STIs, mentions three aspects of imaginaries -- *scale*, *convergence* or *divergence*, and *technology* -- that are still highly relevant to discussions of the energy transition. We use them in this paper to help clarify some current difficulties with the use of STIs in ERSS. STIs fall squarely within the repertoire of interpretive analysis, a branch of social science that concerns itself with meaning, sense-making, and subjectivity. The energy literature, by contrast, has tended to use STIs as a positive *explanatory variable* to explain which, where and how transitions happen. Instead of seeing imaginaries as emerging out of the thickness of human experience, this approach tends to black-box the imaginary as if it drops ready-made into history and drives its development toward deterministic ends.

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[6] B. Anderson, Imagined Communities: Reflections on the Origin and Spread of Nationalism, Verso, London, 1991.

[7] C. Taylor, Modern Social Imaginaries, Duke University Press, Durham, 2003.

[8] C. Strauss, The imaginary, Anthropological Theory, 6 (3) (2006) 322-344.

[9] S. Jasanoff, The idiom of co-production, in: S. Jasanoff (Ed.), States of Knowledge: The Co-Production of Science and the Social Order, New York, Routledge, 2004, pp. 1-45.

[10] S. Jasanoff, Image and imagination: The formation of global environmental consciousness, in: P. Edwards and C. Miller (Eds.), Changing the Atmosphere: Expert Knowledge and Environmental Governance, Cambridge MA, The MIT Press, 2001, pp. 309-337.

Understanding how imaginaries recast meanings of social life opens up deeper, more probing questions about what transitions are and what makes them desirable. STIs, in particular, make sense of how seemingly technical terms such as "sustainability" or "transitions" shape and give direction to a variety of subjectivities and social experiences. Importantly, the STI approach avoids the trap of collapsing many possible transitions into only one imaginable "global" transition. In particular, we can ask how *the* global sociotechnical transition to renewable energy has become singularized at the expense of other notions of renewability that are also circulating in any culture at any moment.

To understand how renewable energy comes to appear as the only, indeed inevitable, response to a perceived environmental crisis requires us to ask how new ideas take hold across entire societies. How in particular can the three dimensions of transition we identified above -- *scale*, *convergence* or *divergence*, and *technology* -- be translated to address interpretive questions such as these:

- What new scales of collective-making come into play, and how are existing collectives reimagined, as energy sustainability becomes *the* renewable energy transition?
- How do prior, even everyday, understandings of power, energy or renewal get subsumed into trajectories of technologically mediated progress, and the kinds of subjectivities that those trajectories call forth?
- How does the "technological fix", as a public performance of sustainability, shift attention away from the dynamics of society and politics to the fixity of materials?

Importantly, these questions attempt to make sense of transition from the standpoint of the people caught up in such a process, how it is lived and experienced, and the normative stakes in and desirability of transitioning from one life world to another.

Making Scales?

Seen as explanatory variables, STIs are used to refer to the imaginations of nation-states or other collectives (e.g., social movements) as if these are fixed in time and space. An interpretive, co-productionist approach sees STIs instead as a means through which *scale* is constructed in transitions such as the global move toward renewables.

STIs, to begin with, are not tied to particular geographic scales. A common misunderstanding is to look only at the *nation* or the *state* as spaces where imaginaries are constructed. For example, Sharlissa Moore uses the term "sociotechnical imaginaries" specifically to refer to *national* imaginaries for renewable energy development in Morocco.[11] She speaks about STIs as placing the emphasis on the "state and on policy" and "how nation-states imagine what a 'good life' would be."[12] Elsewhere authors have critiqued STIs' preoccupation with the role of "state or transnational actors."[13] These critics fault STIs for foregrounding "expert perspectives as the

[11] S. Moore, Sustainable Energy, Transformations, Power, and Politics: Morocco and the Mediterranean, Routledge, New York, 2019.

[12] Moore, pp. 7-8.

[13] J.M. Smith & A.S.D. Tidwell, The everyday lives of energy transitions: Contested sociotechnical imaginaries in the American West, Social Studies of Science, 46 (3) (2016) 327-350.

standard, *normal*, and *institutional* perspectives of entire nation-states," at the expense of "the lived experience of everyday people."[14]

These interpretations often cite the definition of STIs in Jasanoff and Kim's 2009 comparison of the development and regulation of nuclear power in the US and South Korea. Here, the authors referred to STIs as "collectively imagined forms of social life and social order reflected in the design and fulfillment of *nation-specific* scientific and/or technological projects."[15,16] An important point of the analysis, however, was to ask how "everyday people" come to buy into nation-specific visions, by performing the practices of state-making, not to set up the nation or state as primary analytic variables.[17]

If Jasanoff's earlier work on imaginaries looks at the construction of the global ("Image and Imagination") and the nation-state ("Containing the Atom"), the later *Dreamscapes* synthesis illustrates how constructions of the collective good can get made at manya variety of scales. Here it becomes clear that the ambition of STIs (as of co-productionist STS more generally) is to "investigate how, through the imaginative work of varied social actors, science and technology become enmeshed in performing and producing diverse visions of the collective good, at expanding scales of governance from communities to nation-states to the planet."[18]

More generally, STIs allow us to interrogate scale as an *actors' category*, asking the right interpretive questions (e.g., what scales do actors themselves appeal to in introducing or implementing projects?), not as an *analysts' category*, a matter of classifying the imaginary and explaining its effects using the right social science variables (e.g., state / local / global) as drivers of action. The key question for energy research on global transitions is to ask how actors construct and make sense of the "global," and the stakes of establishing collectives, agendas, and indeed forms of life at such a scale -- and not at others that may be more immediate and tangible. In other words, to understand global sociotechnical transition through STIs is to examine how actors *construct* the "global" scale of such a transition -- and ask whose (or what) ways of knowing and being are left out of that imagination.

Convergence or *Divergence?*

Used as explanatory variables STIs are often invoked to point to the dominance of one imaginary or the existence of a multiplicity of "contested" imaginaries. Whether an STI is dominant or contested is, however, less important than questions of how imaginations of the world come to fit together in ways that either *converge* or *diverge*.

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[14] Tidwell & Tidwell pp.

[15] S. Jasanoff & S.-H. Kim, Containing the atom: sociotechnical imaginaries and nuclear power in the United States and South Korea, Minerva, 47 (2009) 119-146

[16] My emphasis. Ibid.

[17] Indeed, co-production requires the inclusion of a variety of actors in order to interpret different social understandings against one another.

[18] *Dreamscapes*, p. 11.

Dominant imaginaries are everywhere. Some accounts, for instance, examine how the state controls the instruments and practices to define a dominant energy imaginary, marginalizing others with insufficient power or resources.[19] The state can construct the public as "passive", like the consumer of the "future Smart Grid" in Norway, thereby depriving citizens of voice.[20] Dominant imaginaries can act as "frame keys" that subsume local memories into national imaginaries, as in the case of U.S. biofuels[21], or "carbon neutral" agenda-setting for cities.[22] Such accounts explain how similar agendas come to dominate in vastly different locations. Thus Gross et al. use STIs to explain the relative uniformity of air quality action plans, and environmental policy more broadly, across disparate urban contexts in Europe, East Asia and North America.[23]

On the flip side, imaginaries can be seen as multiple or "contested".[24] Contested imaginaries are often seen as more inclusive and democratic. Contestation goes on at the level of the material "stuff" of the imaginary, especially in choices between fuels, such as biogas or electricity[25]; or between existing and future technologies, such as the electric vehicle challenging the traditional automobile.[26] Contested imaginaries need not, however, be positive from the standpoint of renewables or sustainability, as in Europe, where the controversial "shale gas imaginary" has challenged the smooth transition to renewables.[27] Nor must contestation always lead to democratic consensus, as in the case of U.S. biofuels where promotions of energy independence were met with resistant local "counternarratives."[28]

This body of work raises important points about how (dominant) imaginaries can crowd out the space of imaginative possibility and how (contested) imaginaries can open up imaginative spaces. Yet these are not "independent" variables that have ontological status as either singular or multiple. Instead, STIs are if anything "dependent," in the sense that they can be pieced together from dynamic repertoires of collective sense-making: around which collectives form,

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[19] L.L. Delina, Whose and what futures? Navigating the contested coproduction of Thailand's energy sociotechnical imaginaries, Energy Research & Social Science, 35 (2018) 48-56.

[20] I.F. Ballo, Imagining energy futures: Sociotechnical imaginaries of the future Smart Grid in Norway, Energy Research & Social Science, 9 (2015) 9-20.

[21] W.M. Eaton, S.P. Gasteyer & L. Busch, Bioenergy futures: Framing sociotechnical imaginaries in local places, Rural Sociology, 79 (2) (2014) 227-256.

[22] L. Tozer & N. Klenk, Discourses of carbon neutrality and imaginaries of urban futures, Energy Research & Social Science, 35 (2018) 174-181.

[23] P.L. Gross, N. Buchanan & S. Sané, Blue skies in the making: Air quality action plans and urban imaginaries in London, Hong Kong, and San Francisco, Energy Research & Social Science, 48 (2019) 85-95.

[24] D. Hess, Public as threats? Integrating science and technology studies and social movement studies, Science as Culture, 24 (1) (2015) 69-82.

[25] A. Mutter, Mobilizing sociotechnical imaginaries of fossil-free futures – Electricity and biogas in public transport in Linköping, Sweden, Energy Research & Social Science, 49 (2019) 1-9.

[26] A. Wentland, Imagining and enacting the future of the German energy transition: electric vehicles as grid infrastructure, Innovation: The European Journal of Social Science Research, 29 (3) (2016) 285-302.

[27] M. Kuchler & G. Bridge, Down the black hole: Sustaining national socio-technical imaginaries of coal in Poland, Energy Research & Social Science, 41 (2018) 136-147.

[28] J. Schelhas, S. Hitchner & J.P. Brosius, Envisioning and implementing wood-based bioenergy systems in the southern United States: Imaginaries in everyday talk, Energy Research & Social Science, 35 (2018) 182-192.

and historically have formed, thereby enabling the stabilization of certain institutional features and futures which gain communal assent. What is seen as a static dominant imaginary can always be questioned in terms of how imaginations of the world came to *converge* toward that endpoint, in what Ludwik Fleck calls a "harmony of illusions."[29] Equally, one may ask why multiple or contested imaginaries *diverge*, and why the attendant STIs failed to harmonize. STIs draw upon such resources as constellations of memories, images, discourses, social practices, and material achievements that can be assembled to produce or reinforce particular expressions of collective choice. Such expressions can encourage convergence toward a particular imagination, for example, sustainability as "renewable energy," but only because prior and tacit understandings provided the stuff out of which the new imaginative possibilities were made. The question for STI research becomes not how to problematize sustainability by asserting that imaginaries are "contested," and thereby open up democratic possibilities or resist "hegemony." Rather, STIs point to the multiple, contested and contingent origins of imaginaries and the resources with which they are constructed--and, even, without which alternatives their eliminated.

In our cases we invoke STIs to show how imaginaries of sustainability came to include renewable energy and vice-versa, making the two effectively synonymous. Similar to Hajer and Pelzer's work on "techniques of futuring," we are interested in the ways that actors "share particular orientations."[30] However, our work emphasizes how collective actors come to imagine their world and its futures as ontologically durable or distinct.

A Technological Fix?

The explanatory variables approach places the imperatives of technological transition, and the need to explain its pace or probability, ahead of the important interpretive question: why did transitions to sustainability get locked into the technological fix as the right answer to a grand social problem?

STIs shift the analytic focus of work on social transformations away from specific technologies and their effects (in STS terms an *actant*-centered view) toward questions about how sociotechnical projects enact visions of the collective good (more an *actor*-centered view). Put differently, in the STI framework, "questions of how to power modern social life have always been bound up with political imaginations, tacit or explicit, about the costs and benefits of technological change."[31] The framework is particularly well suited to surfacing the human-material relationships latent in technological projects.

The focus on actants in STS stems from the ANT school. One effect of following actants, however, is to leave unquestioned the assumptions of actors trying to effect materialist "transitions." Even accounts based on the STI framework, for example Johnstone and Stirling's

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[29] Ludwik Fleck, *Genesis and Development of a Scientific Fact*, University of Chicago Press, Chicago, 1981, pp. 27-28.

[30] M.A. Hajer & P. Pelzer, *2050—An energetic odyssey*: Understanding 'techniques of futuring' in the transition towards renewable energy, Energy Research & Social Science, 44 (2018) 222-231.

[31] S. Jasanoff & S.-H. Kim, Sociotechnical Imaginaries and National Energy Policies, Science as Culture, 22 (2013), 189-196.

"sociotechnical transitions," tends not to question why transitions are seen as having a technological imperative. Rather their work examines the social and political factors that explain what makes a transition, such as the phaseout of nuclear power, more or less likely.[32] A missing "external" social variable (for example, "qualities of democracy") can then be identified as making an dependent variable of sociotechnical transitions more likely to be achieved than the "internal" path-dependent aspects of particular technologies (such as industry strength, sunk capital or R&D expenditure). ANT rejects the linear language of explanatory variables that are either dependent or independent with a language of networks and their enrolled components and negotiated nodes. Yet, implicit in ANT is the idea that to change the non-human component of a network is to change the human components as well. With renewable energy, it is thought that replacing the non-human of the non-renewable with a renewable non-human will lead to a "transition" to a new state called "sustainability" -- a view perfectly in keeping with ANT.

By contrast, the STI approach is at its most powerful when it brings a humanistic lens to understanding what makes ourselves, our world and our collective future sustainable. It also foregrounds social and political themes, including: social justice, inequality, democracy and even the possibility of "bottom-up" alternatives that might emerge from the Global South.[33] Where STIs differ most from a technology-centered account of sustainability (like ANT) is in problematizing the notion of transition itself, in turn questioning the normative ends implied by such a process, and what might be missing in technology-driven understandings of the human condition.

Applying these ideas to two case studies below, we show how the global sociotechnical transition to renewables rests in effect upon the *same* imagined human-nature configurations as global development did before sustainability became the watchword for progress: far from changing underlying imaginations, renewables reinscribe the determinist view of technology as the key to social and political change, a view consistent with actant-centered accounts of the world. We argue that the analytically important symmetry is not that between actors and actants, but rather in the symmetric interrogation of the STI of renewable energy and the unexamined imaginaries that did not stem from the materialist conceits of the global sociotechnical transition.

III. Climbing the Energy Ladder: Solar Power and Social Progress in Senegal

A prominent "alternative" development NGO in the global South, headquartered in Dakar where some of our research was conducted in 2015-2016, features energy at the top of its agenda.[34] An analysis of its projects illustrates how it has become captive to STIs that systematically equate

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[32] P. Johnstone & A. Stirling, Comparing nuclear trajectories in Germany and the United Kingdom: From regimes to democracies in sociotechnical transitions and discontinuities, Energy Research & Social Science, 59 (2020) 101245.

[33] J. Marquardt & L.L. Delina, Reimagining energy futures: Contributions from community sustainable energy transitions in Thailand and the Philippines, Energy Research & Social Science, 49 (2019) 91-102.

[34] This case is based on research that one of the co-authors, Hilton Simmet, conducted in Senegal during 8 months of fieldwork and participant observation with a prominent environmental development NGO. The name of the NGO has been anonymized to protect its work and its workers. Simmet's research work was supported by a fellowship from the U.S. Fulbright Scholar Program, in 2017-2018, and the Institute of International Education U.S. State Department).

ideas of achieving sustainability with global and technology-centered imaginaries that also imagine people as needing to be detached from their cultural context and made to circulate as productive agents in the global economy.

A Phase Transition

The World Bank sponsored Sustainable Energy for All (SEforAll) has made "climbing the energy ladder" via "tiers of energy access" central to campaigns to escape poverty.[35] As if in a nod to the climbing metaphor, our NGO designated the two top floors of its six-story office building to its ENERGY PROGRAM: a daily office routine required climbing up many flights of stairs, physically performing the upward imaginary of sustainability, or sustainable development ("*développement durable*"). ENERGY project graphics featured upward pointing arrows depicting "diffusion" and, in one case, a pyramid connecting "people" at the wide bottom of the graphic and energy scaling the narrow top.

People are ostensibly the focus of sustainable development. Indeed, the NGO's logo featured a small person in the center of a globe, perhaps in homage to the human being that Senegal's first President Leopold Sedar Senghor said should be at the center of development. Images on the ENERGY PROGRAM pamphlets displayed large groups of people sitting around in deliberation, depicting the local scale of ENERGY initiatives. Some people pictured with solar panels and others doing homework using LED lamps and still others examining the latest improved baking oven ("*boulangerie améliorée*").

Yet, though *people* were supposed to be at the center of sustainability, in the end it was material *products* that would be upscaled: products intended to move up the value chain ("*chaines de valeur*") akin to electrons moving up the shells of an atom. Midas-like, ENERGY thus became a catalyst for turning agricultural goods into gold. The heat from improved ovens or the photons hitting solar panels enabled these products to jump out of the rural areas where they were located into the higher spheres of a national, and even international, "green economy" ("*économie verte*").

One illustratration of such a phase transition, from local to global scale, was the effort to turn unproductive milk into packaged products, collected in rural Senegal and Mauritania, to be sold in Dakar markets. The "milk progress" project would install a "platform," in rural areas to establish a packet of services that included three major components: i) rural electrification, ii) microfinance and iii) milk collection and sales. Local "mini-platforms" would collect milk from producers which would be logged and sold to regional "large platform centers." Thus platforms would connect producers to milk markets, using solar electrification as the primary vehicle for the storage of milk and packaged milk products.

The discourse of scaling the energy ladder is new, but the aims represent hardly any rupture from the many projects of development that came before it. Those past goals were virtually identical, alchemically transforming human-nature relationships from close ties between people and the land into circulating material and economic modes of production leading to increased revenues.

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[35] M. Bhatia & N. Angelou, Beyond Connections: Energy Access Redefined, ESMAP Technical Report, 008 (2015), World Bank, Washington, DC. https://openknowledge.worldbank.org/handle/10986/24368

Renewable photons from the sun converted into electromagnetic signals would make even packets of milk move, though the people doing the daily milking might not. The human scale of sustainable development remained firmly in place.

"Perennializing" Reproduction

In Senegal, renewable energy initiatives attempted to institutionalize "training" and "coaching" exercises that made people into entrepreneurs whose activities could be "perennialist" through self-financed loans. To "perennialize" their work, people were asked to use their revenues to pay back micro-loans given to finance their micro-grids. With the solar milk project, for example, women were expected to increase their revenue by 30%. Through training and coaching these women were to become "female entrepreneurs." Perennializing sustainability projects changes the networks of dependence. Both villagers and development agencies, including the ENERGY PROGRAM, became more reliant on funding dollars from the global North. They had to transform themselves in order to receive these funds. ENERGY PROGRAM officers and local government officials twisted themselves into pretzels in order to work out a strategy for receiving a 1,000,000 EUR grant from the European Union's Conference of Mayors. "We can work on climate change," one supervisor said, and "valorise" ("*valoriser*") things like this waste, but "we also need [people] to change their behaviours (*comportements*)."

During one discussion of the EU Conference of Mayors grant, the development officers were in suits and ties standing in an empty lot where they planned to "work on climate change" by installing "solar lamps" ("*lampadaires solaires*"). All around were "waste" products including empty bottles and stray bits of plastic, not to mention the stray goats and children darting in and out. The only unofficial adult was not wearing a suit but a traditional blue *boubou* (garment), scarf and hat. He asked to join the conversation only to be told "no" ("*déedéet*"). Clicking his tongue he complained that "some of these men" (referring to the local officials) "were my *talibés*"or religious students. Only now, instead of being asked to memorize lines from the Koran, the students were seeking to transform waste, using "solar lamps," into a "perennialized" stream of European funding for the ENERGY PROGRAM.

What was being perennialized through ENERGY projects was a relationship of actors on the ground to sustainable development dollars. It was also the view that people needed to change toward some imported model of productive behavior in order to qualify for those dollars, and in time to produce some themselves. Economic development has been concerned with the inability of key actor groups, like women and youths, to be economically productive.[36] The shift from sustainable development to renewable energy continues the same mode of thinking. Women would transition through solar energy to a perennialized way of life or remain stuck in the unproductive rituals of child-minding, subsistence agriculture and prayer. Indeed, calls from European mayors stood in marked contrast to calls from the *muezzin* who called people to prayer five times daily, asking them to detach themselves from the material to the spiritual domain.

Technological Inputs and Material Outputs

[36] C. Udry, Gender, agricultural production, and the theory of the household, Journal of Political Economy, 104 (5) (1996) 1010-1045.

The performance of sustainability invariably involved demonstrations of solar electrification, whether in pamphlets or the distribution of technologies as metonyms for sustainability. Sustainability as renewable energy joined a long list of material improvements, from cookstoves to GM rice, meant to improve the conditions of the world's poorest.[37] Renewable energy was the technological fix that would achieve this. The ENERGY PROGRAM itself was littered with artifacts such as small solar cells, lanterns, batteries, and endless numbers and configurations of lights that sat in small boxes that were seemingly never moved or opened.

Mini-platforms were diagrammed as "transformation units" ("*unité de transformation*"). These included as "inputs" installed equipment to "maximize cow productivity," through solar refrigeration ("conservation best practices") and the creation of novel milk products that would be exchanged for "$$$". But "outputs" also included "$$$" and the more high-minded (though equally materialist) ambitions of "improvement of the food situation of the population." Specific outputs were listed as increased production, reduced cost and increased sale of milk products. Development economists call this increased "$$$" a change in "total factor productivity": also known as "*technology*."[38]

People were an afterthought. They were included in these projects as part of training and information dissemination. In other words, people were in the service of the mini-platform -- not the other way around. One person would act as a "technician," another as an "accountant" to control revenues, and a third a "manager" to oversee the other two and interact with NGO officials or village people. Involvement was otherwise limited to buy-in on the part of milk selling entrepreneurs. Once the renewable energy system was put in place, sustainability became almost an afterthought, as presenters' slides mentioned that "rules" designed to make the whole thing work "must incentivize project objectives, *including* sustainability" (my emphasis).

The number of references to technology, and the conversion of human-nature relationships into technologized terms, was dizzying. Day in and day out we heard about technologies to improve farmer's lives while, in the office, mundane technologies barely functioned. The internet, for example, was so slow that it was hardly usable for research, let alone correspondence. It was not a function of internet technology alone, but in part of people. When the workers were away from the office, during Friday afternoon prayer for example, the internet worked perfectly. Yet, even though social practices proved key to the "flows" of office life, it was imagined that cheap solar cells spread out across millions of African villager's hands would bring sustainability to the continent.

IV. Capturing the Sun in Karnataka

As part of the Belmont Forum project on the Governance of Sociotechnical Transformations (GoST),[39] we traveled to Bangalore in the Indian state of Karnataka in January 2020 to attend a workshop organized by our project partners, Leo Saldanha and Bhargavi Rao of the Environment

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[37] https://www.washingtonpost.com/opinions/these-cheap-clean-stoves-were-supposed-to-save-millions-of-lives-what-happened/2015/10/29/c0b98f38-77fa-11e5-a958-d889faf561dc_story.html

[38] C. Jones, The facts of economic growth, Handbook of Macroeconomics, 2016.

[39] This trip was part of the project Belmont Forum Collaborative Research: Governance of Sociotechnical Transformations. The US component of the project is funded by NSF Award No. 1856215.

Support Group (ESG). Our trip included a visit to Pavagada Solar Park, as of this writing considered the second largest solar park in the world. Completed in 2019 and spread out over 53 square kilometers, it has a capacity of 2.050 GW. We were not sure what we would see in any way different from innumerable other solar energy installations, big and small, that we had seen in other parts of the world, but this trip proved a revelation.

As in the Senegal case, the Pavagada project imported a material vision of renewability -- how to convert the sun's rays into electricity with the aid of solar panels -- into a cultural context where people had lived with the sun for centuries, feeling no need to capture it materially. The huge transformations wrought on the land with the building of the solar park showed (as in Senegal) how local livelihoods can be "transitioned," or upscaled, into a global economy, how the diversity of manners and mores becomes standardized and absorbed (i.e. converge) into fewer exemplars, and how the materiality of the "renewable" metonymically displaces all other ways that people and animals previously had of living renewably with that patch of Earth.

January 15, 2019, the day we visited Pavagada, was a major holiday in South India, the *Makara Sankranti*, celebrated to mark the change of seasons from the nadir of winter to the auspicious season ahead. It is one of the few Indian holidays keyed to the solar calendar, and hence a particularly appropriate day to view one of the latest phases in the perennial human quest to catch the sun in flight. There was a festival feeling in the air as we drove out from Bangalore. Our way was marked by all the clashing juxtapositions of ancient and modern that make up India's temporal and experiential tapestry. Within a few short miles, one can travel back and forward by several centuries, as if time sees no need to be strictly linear. We passed by the impressive monolith at Madhugiri, rearing its massive bulk out of the dusty land and sheltering temples and forts built over the course of a thousand years. In the small towns on the way, open streetside markets displayed local produce on the ground under makeshift tents to give the sellers shade. Everywhere there were signs of devotion, shrines at the bases of trees, colored rice flour designs at doorways, occasional cattle wearing garlands and painted horns in honor of the season and the day. It was normal life in India, vibrant, varied, colorful, informal, and renewable.

At the solar park, the scene changed. The face of the land turned from sandy brown to dusky blue, the color of solar panels stretching in every direction as far as we could see. Signs of life and habitation vanished. We came to an entrance, presided over by a single guard who let us drive in after Leo somehow established our bona fides. The man had been, till recently, a farmer, but along with his brothers he had sold the ancestral farmland in return for a fixed income for the next 25 years. Now he wore a uniform under the hot southern sun, and his day seemed exceptionally enlivened by this chance group of strangers who had simply happened to drive in. Yet, as he told Leo, he was happy enough with his bargain for life, an assured income in place of the uncertainties of the changing seasons in an inhospitable, arid land.

The park was still new enough for some packing crates to be lying around. These indicated that the panels had come from China, testament to the supply chains that complicate bland notions of energy self-sufficiency in India. Despite the newness, the panels themselves were already dusty, and we saw the irrigation devices needed to hose them down. Each panel requires 2 liters of water per cleaning, a huge stress on scarce groundwater resources, although -- in another example of the park's globally networked status -- an Israeli robotics firm is providing "water-

free cleaning" at a Pavagada site operated by a Finnish electricity company.[40] Outside the barbed wire fence a few goats wandered, reminders of the rights that local shepherds once had to graze their flocks there. Without title or ownership, they had lost those rights once the government enclosed and leased the land to power companies. Now some speculated that shepherds and their flocks might be allowed back in, earning a second lease on life, to control the vegetation growing between the panels and creating a fire hazard.[41]

For the dispossessed peanut farmers no comparable relief is in sight. Land once claimed for utility-scale solar power production is unlikely to be returned to agricultural uses even if a park is decommissioned. The installation of ground level solar panels requires grading and compacting the soil and inserting poles or other supports into a fixed concrete bed. The solar infrastructure uproots plant life, leaving little prospect for it to flourish again even if the panels are removed. Since developments like Pavagada are still so recent, there has been little or no experience with decommissioning these systems, not even to dispose of the panels once they have outlived their useful life. It is clear, and not only from negative ads by the fossil fuel industry,[42] that recycling and waste management from sites such as Pavagada may pose substantial environmental challenges in the future, challenges that may be hard to meet in political contexts where regulation has tended to be haphazard and unenforceable.

From the solar park we drove to a small outlying village where men of varied ages were lounging on a tented platform in a square in front of the temple. Some immediately engaged Leo in conversation, evidently mistaking him for a power company representative and charging him with having driven them out of work. Former smallholders, they said, had been forced into bad bargains on the sale of their land; the return was not economically sustainable and besides they now had nothing to do. The nearest source of employment was Bangalore, 150 kilometers and three hours away by road. Leo explained that *we* were not part of the problem, apparently to everyone's satisfaction. As we piled back into the car, the men requested us to stay long enough to have an afternoon coffee. Our site visit ended with coffee and snacks, offered by village women with whom we foreigners could not speak in words, but only in the universal language of smiles and hospitality that are also among India's traditional renewables.

On a tropical winter day, it grew dark early as we drove back to Bangalore. A lively crowd had gathered around an array of small fires in one small town square on the way back and we pulled over to see what was happening. It was a version of the fire ceremony that marks the *sankranti* in that region. People light bonfires on roads, and in some places it is customary to drive one's cattle though the flames, some say as part of a purification ritual to get rid of bugs and dirt. Here it seemed more to display the prowess of youthful males as they took running leaps across a low barrier of flames lit with smoldering rags. Hilton, as the youngest man in our group, was urged, indeed egged on, to join the fun, and he acquitted himself well with the three jumps the ritual required. That done, we returned to Bangalore, reminded that terms like *renewable*, *energy*, and

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[40] P. Fairley, The Pros and Cons of the World's Biggest Solar Park, *IEEE Spectrum*, January 22, 2020, https://spectrum.ieee.org/energy/renewables/the-pros-and-cons-of-the-worlds-biggest-solar-park.

[41] Id.

[42] M. Shellenberger, If Solar Panels Are So Clean, Why Do They Produce So Much Toxic Waste? *Forbes,* May 23, 2018, https://www.forbes.com/sites/michaelshellenberger/2018/05/23/if-solar-panels-are-so-clean-why-do-they-produce-so-much-toxic-waste/?sh=48f03c64121c.

power have very different meanings in the cultural world from the fixed and immutable meanings built into the sea of solar panels we had seen.

V. Conclusion

In the engineering imagination that has dominated thoughts of a sustainable energy transition, the word "renewable" has come to be coupled to one or another material aspect of nature that we deem inexhaustible: sun, wind, water, and the incompletely unlocked forces in the nucleus of the atom. Our cases show that the attempt to effect a "global" sociotechnical transition depends on prior work to establish the primacy of some imaginations over others, and in the vignettes from Senegal and India we see that the very idea of renewal was a site where meanings clashed and eventually converged. Critically investigating the construct -- and construction -- of renewable energy enables us to revisit and refine the theoretical concept of sociotechnical imaginaries along the axes laid out in this paper: *scale*, *convergence* or *divergence*, and *technology*. In each case study, we saw that harnessing the force of the sun to generate electricity for human needs required the assembling of complex networks of money and materials, of land and labor, of expertise, laws, institutions, and of people to service them.

Building renewable energy systems, whether for solar panels in rural Senegal or establishing a mega solar park in India, can be seen, in STS terms, as textbook instantiations of actor-network theory (ANT). Indeed, one might even assert not too fancifully that, in these projects, the energetic non-human actant acquires a kind of agency, because it seems to reorganize an entire world of production around its electrifying potential. Sun, wind and water engage, for all practical purposes, in symmetrical relations with humans, as in a classic ANT story, enabling modern lives, especially urban ones, to function as productively as people want them to. The ingenuity that is so central to ANT accounts seemingly functions as a driver of progress. The human and the nonhuman components of the renewable energy network collaborate to transition the previously wasteful, extractive practices of energy production toward a clean, green, and sustainable future.

Our analysis of two solar energy projects in the global South underscore why the ANT account falls short as a framework for critical analysis, and how the STI approach illuminates hidden recesses of the stories that ANT misses. In both cases, we see that capturing the radiant heat of the sun is not a symmetrical enterprise. True, solar radiation seems to hold human ingenuity captive in these projects, but only because that subjugation follows developmental pathways developed elsewhere and at other times. The ideas of progress that animate sustainable energy developments in Senegal and South India reflect particular imaginaries of advancement that promote and foreground certain social virtues and, reciprocally, background or demote others. Thus, large-scale electrification favors urban economies of capital production and financialization over rural ones of labor close to the land, mental labor over physical, monetary wealth over other social capital, and the promise of growth over the reality of sufficiency, often relabeled as poverty. The focus on the materiality of projects leaves little room for exploring what happens to situated human subjects whose imaginations of a self-renewing future, sanctified in prayer and ritual, are suddenly, and rudely, displaced in favor of forms of life centered on radically different imaginaries of productive human-nature relationships.

Our examples also address some of the recurrent puzzles we have identified in efforts to analyze the dynamics of energy production through the lens of STIs, showing that these are not so much questions to be answered as openings to reflections on the existence of alternative worlds. As a term that lends specificity to the broad phenomenon of co-production, STIs help reveal the ways in which the material and normative dimensions of future-making are bound up together -- packed, in our essay, into the concept of renewables. We see, first, a collapsing together of scales. An everyday term that has acquired technical meaning in the context of the global energy transition is translated into local contexts where there was no home-grown demand for any transition, let alone to renewable energy, and suddenly the locals are connected by smart telephone apps, and thrust onto a world stage where their voices are rendered small and insignificant. We see, too, how the power of the global imaginary erases the counter-narratives of those who may have harbored other dreams than abandoning their earthbound, but centered, livelihoods to become village entrepreneurs or find work in distant, anonymous cities. And we see the technology of solar power being presented as a "fix" to people who must now tangle with impersonal machines installed to render their livelihoods more productive, though their own characterization of their problems and vulnerabilities before these projects came might have focused on anything but a need for more electricity.

The point of seeing the world as an interplay of STIs is not to romanticize, neither the old nor the new, neither the ancient and traditional nor the rootless, mobile and modern. It is to acknowledge that we are, all of us, engaged in pre-visioning our purposes and our futures, but the power to play history forward is not equally distributed among the peoples and societies of the world. And therefore an STI around which a bigger network has coalesced may indeed erase and replace a smaller one without any full accounting of which was the more sustainable or more virtuous.