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Grassroots Innovation Systems for the Post-Carbon World: Promoting Economic Democracy, Environmental Sustainability, and the Public Interest

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Grassroots Innovation Systems for the Post-Carbon World

PROMOTING ECONOMIC DEMOCRACY, ENVIRONMENTAL SUSTAINABILITY, AND THE PUBLIC INTEREST

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INTRODUCTION

Our strategies to achieve a post-carbon world often involve technological development. Policymakers, non-governmental organizations (NGOs), and entrepreneurs invest heavily in clean energy technologies, and the recent Paris Agreement assumes that these investments will pay off to mitigate climate change.[1] Meanwhile, engineers and physicists have begun to explore the potential of large-scale geoengineering technologies—which promise to cool the earth by managing solar radiation or aim to remove carbon dioxide from the atmosphere—to facilitate these efforts.[2]

While many of these interventions have focused on the developed world, emerging economies have not escaped this

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[1] *See* FRANKFURT SCHOOL FS-UNEP COLLABORATING CENTRE FOR CLIMATE & SUSTAINABLE ENERGY FIN., GLOBAL TRENDS IN RENEWABLE ENERGY INVESTMENT 2016 (2016), http://fs-unep-centre.org/sites/default/files/publications/globaltrendsinrenewableenergyinvestment2016lowres_0.pdf [https://perma.cc/BYB2-9DA8]. NGO investments in clean energy technologies include the efforts of groups like the Global Alliance for Clean Cookstoves, which is discussed in detail below.

[2] *See* NAT'L RESEARCH COUNCIL ET AL., CLIMATE INTERVENTION: REFLECTING SUNLIGHT TO COOL EARTH (2015).

technological enthusiasm.[3] Rather than transition with the use of "dirty" technologies, global negotiators have argued less-developed countries should take advantage of alternative sources of energy.[4] This is particularly urgent because rapidly industrializing countries like India and China are among the largest emitters of carbon dioxide.[5] To achieve this goal, NGOs and governments across the developed world have initiated hundreds of projects focused on powering developing countries with alternative sources—including solar energy.[6] Other seemingly simpler initiatives include replacing rustic cookstoves with "clean" ones that promise to reduce carbon emissions as well as air pollution, with the ultimate goal of improving both public health and the environment.[7]

While many of these technological interventions hold promise, they have proven quite difficult to implement—especially when deployed in developing countries. In addition to economic challenges, these technologies have faced both social and political resistance. Clean cookstove uptake, for example, has been quite slow. Some citizens are unhappy with the taste and quality of the foods they produce, while others are perfectly happy with their current cooking methods and see no need to

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[3] This characterization of countries as "developed" or "developing" is comparative. Developed countries, including the United States and much of Europe, are generally more industrialized and have higher per capita income levels than developing countries like China. For specific classifications, see *Composition of Macro Geographical (Continental) Regions, Geographical Sub-regions, and Selected Economic and Other Groupings*, UN DATA, http://unstats.un.org/unsd/methods/m49/m49regin.htm#least [https://perma.cc/ZB65-Q5BS]; *World Bank Country and Lending Groups*, WORLD BANK, https://datahelpdesk.worldbank.org/knowledgebase/articles/906519 [https://perma.cc/35Z8-SXL7].

[4] The World Resources Institute is one of the leading global negotiators in this area. *See Q&A: Policies for Renewable Energy in Developing Countries*, WORLD RES. INST. (Dec. 13, 2010), http://www.wri.org/blog/2010/12/qa-policies-renewable-energy-developing-countries [https://perma.cc/JK9V-PUNP]; Anna Leach, *Race to Renewable: Five Developing Countries Ditching Fossil Fuels*, GUARDIAN (Sept. 15, 2015), https://www.theguardian.com/global-development-professionals-network/2015/sep/15/five-developing-countries-ditching-fossil-fuels-china-india-costa-rica-afghanistan-albania [https://perma.cc/T8NR-8XYD].

[5] Hasan Murat Ertugrul et al., *The Impact of Trade Openness on Global Carbon Dioxide Emissions: Evidence from the Top Ten Emitters Among Developing Countries*, 67 ECOLOGICAL INDICATORS 543, 544 (2016). In 2015, 30% of the total global carbon dioxide emissions came from China, 15% from the United States, 10% from the European Union, and 6.5% from India. JOS G.J. OLIVIER ET AL., PBL NETH. ENVTL. ASSESSMENT AGENCY, TRENDS IN GLOBAL CO_2 EMISSIONS: 2015 REPORT 4 (2015), http://edgar.jrc.ec.europa.eu/news_docs/jrc-2015-trends-in-global-co2-emissions-2015-report-98184.pdf [https://perma.cc/J9VF-M6ST].

[6] *See* Kamil Kaygusuz, *Energy for Sustainable Development: A Case of Developing Countries*, 16 RENEWABLE & SUSTAINABLE ENERGY REVIEWS 1116 (2012).

[7] *Our Mission*, GLOB. ALL. FOR CLEAN COOKSTOVES, http://cleancookstoves.org/about/our-mission/ [https://perma.cc/8R6D-MSC3].

change.[8] Efforts to power rural areas with renewable energy technologies have produced some success, but they have also faced serious problems when innovators ignore the dynamics of national, political, and social structures as well as the needs expressed by local communities.[9] And though some scientists and engineers have described geoengineering as a technical solution to the political impasse regarding climate change, many world leaders are wary of committing to the type of long-term, international agreements that are necessary for its success.[10] Can governments, NGOs, and innovators do a better job of predicting—and proactively addressing—these social and political challenges? Can they better harness technology to facilitate a post-carbon world?

This article suggests that they can. To do so, innovators and policymakers must rethink their approaches to both innovation and implementation. Specifically, they must conceptualize technologies as not only complex material objects, but also as sociotechnical systems[11] that are deeply embedded in historical, economic, social, and political contexts that embody particular norms and values. Thus, the innovation challenge for the post-carbon world is not just technical but social and political as well. This article uses this sociotechnical systems framework to argue further that most technology-based international development efforts are rooted in a dominant approach to innovation that inadvertently constrains the implementation of new technologies in less-developed regions of the world. It suggests that, in order to understand the kinds of technology and systems that might successfully

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[8] *See* Burkhard Bilger, *Hearth Surgery: The Quest for a Stove That Can Save the World*, NEW YORKER (Dec. 21, 2009), http://www.newyorker.com/magazine/2009/12/21/hearth-surgery [https://perma.cc/7W32-R576]; ESTHER DUFLO ET AL., HARVARD ENVTL. ECON. PROGRAM, UP IN SMOKE: THE INFLUENCE OF HOUSEHOLD BEHAVIOR ON THE LONG-RUN IMPACT OF IMPROVED COOKING STOVES 2, 18–19, 50, 75 (2012), https://www.hks.harvard.edu/m-rcbg/heep/papers/hanna_dp41.pdf [https://perma.cc/M22M-ESYL].

[9] Simon Bawakyillenuo, *Deconstructing the Dichotomies of Solar Photovoltaic (PV) Dissemination Trajectories in Ghana, Kenya and Zimbabwe from the 1960s to 2007*, 49 ENERGY POL'Y 410, 411 (2012); JUAN LUCENA ET AL., ENGINEERING AND SUSTAINABLE COMMUNITY DEVELOPMENT 2–3 (2010), https://isfcolombia.uniandes.edu.co/images/documentos/lucena.pdf [https://perma.cc/RH8B-CR8Q].

[10] *See* Bronislaw Szerszynski et al., *Why Solar Radiation Management Geoengineering and Democracy Won't Mix*, 45 ENV'T & PLAN. A 2809, 2809–10 (2013).

[11] *See generally* THE SOCIAL CONSTRUCTION OF TECHNOLOGICAL SYSTEMS: NEW DIRECTIONS IN THE SOCIOLOGY AND HISTORY OF TECHNOLOGY (Wiebe E. Bijker et al. eds., 1987) (on sociotechnical systems and methods to analyze them, and how social, historical, and economic contexts shape the design and development of science and technology); SHOBITA PARTHASARATHY, BUILDING GENETIC MEDICINE: BREAST CANCER, TECHNOLOGY, AND THE COMPARATIVE POLITICS OF HEALTH CARE (2007) (on how political and policy context shapes technological development and design).

power the post-carbon developing world, we should carefully study grassroots innovation efforts in those contexts. To do this, it focuses on two examples of grassroots innovation systems in India—The Honeybee Network (THN) and the Self-Employed Women's Association (SEWA).

I. SOCIOTECHNICAL SYSTEMS AND INTERNATIONAL DEVELOPMENT

Scholars from the field of Science and Technology Studies (STS) have long demonstrated that technologies are not simply made up of mechanical components, and their designs and developments are not simply the inevitable results of technical labor.[12] Rather, the construction and ultimate form of technologies reflect the institutions and individuals that manufacture and use them, and serve to stabilize certain moral and social orders.[13] The height of a bridge, for example, can constrain bus traffic and therefore the free movement of low-income individuals who rely on public transportation.[14] Airbag and seatbelt designs reflect assumptions not only about the driver's height, weight, and gender but also about his trustworthiness.[15] Technologies also reflect the norms, values, political culture, and institutional commitments of the communities in which they are made. For example, the genetic test for breast cancer, known as BRCA gene testing, that was developed in the United States, reflects the country's privatized health care system and commitment to using market incentives to stimulate scientific and technological development.[16]

This sociotechnical systems approach can also be used to show that attempts to transfer technology are simultaneously efforts to transfer particular norms, values, and ways of life.

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[12] *See generally* THE SOCIAL SHAPING OF TECHNOLOGY: HOW THE REFRIGERATOR GOT ITS HUM (Donald MacKenzie & Judy Wajcman eds., 1985) (on how technologies should be conceptualized as having both material and social components); HOW USERS MATTER: THE CO-CONSTRUCTION OF USERS AND TECHNOLOGIES (Nelly Oudshoorn & Trevor Pinch eds., 2003) (on how users should be understood as part of technological systems).

[13] *See generally* STATES OF KNOWLEDGE: THE CO-PRODUCTION OF SCIENCE AND SOCIAL ORDER (Sheila Jasanoff ed. 2004) (on the co-production of social and scientific orders).

[14] Langdon Winner, *Do Artifacts Have Politics?*, 109 DAEDALUS 121, 123–24 (1980).

[15] *See* Jameson M. Wetmore, *Redefining Risks and Redistributing Responsibilities: Building Networks to Increase Automobile Safety*, 29 SCI. TECH. & HUM. VALUES 377 (2004).

[16] *See generally* PARTHASARATHY, *supra* note 11. This is clear both in the DNA analysis techniques used in both places as well as their approaches to incorporating genetic counseling into the testing system.

Accordingly, it can help predict controversy and difficulty in technological transfer and diffusion—the proper functioning of a technology in one context does not mean that it will work the same way in another. In fact, even determinations of accuracy are shaped by the social world in which a technology is developed and used.[17] Myriad Genetics, the biotechnology company that became the sole provider of BRCA gene testing in the United States, experienced strong resistance when it tried to expand its testing service to Europe, for example, with scientists, physicians, and patients arguing that it was of poor quality and simply would not work.[18] This resistance was particularly surprising because the U.S. provider marketed its service as a gold standard technology.[19] Because its system clashed with deeply rooted European approaches to health care, the doctor-patient relationship, and the commercialization of science and technology,[20] the company was forced to scale back its ambitions dramatically.[21]

Clean cookstove development and implementation demonstrate that this kind of culture clash is at least as acute in international development efforts, where there is great social and economic distance between producers based in the developed world and users in developing countries. Engineers, policymakers, and NGOs see these technologies as improvements upon traditional biomass cookstoves, which are heated by burning wood, charcoal, animal dung, or crop residue.[22] The traditional cookstoves pollute the environment, are inefficient in their fuel use, and also contribute to deforestation.[23] There are many types of clean cookstoves, but they are all designed to address these health and environmental problems.[24] But for villagers in the developing world, traditional cookstoves are an integral part of their everyday lives.

The idea that clean cookstoves could be vital to developing countries first emerged in the 1970s, when NGOs and governments began to argue that they could alleviate air

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[17] *See generally* DONALD MACKENZIE, INVENTING ACCURACY: A HISTORICAL SOCIOLOGY OF NUCLEAR MISSILE GUIDANCE (1993); PARTHASARATHY, *supra* note 11.

[18] PARTHASARATHY, *supra* note 11, at 189.

[19] *See generally id.*

[20] *Id.*

[21] *Id.*

[22] Harshika Kumari et al., *Comparative Study on Emissions from Traditional and Improved Biomass Cookstoves Used in India*, 2 INT'L J. FOR RES. APPLIED SCI. & ENGINEERING TECH. 249, 249 (2014).

[23] ENVTL. DEP'T, WORLD BANK, HOUSEHOLD COOKSTOVES, ENVIRONMENT, HEALTH, AND CLIMATE CHANGE: A NEW LOOK AT AN OLD PROBLEM 1, 17 (2011), http://cleancookstoves.org/resources_files/household-cookstoves-1.pdf [https://perma.cc/CTH9-4NXS].

[24] *See Stoves*, GLOB. ALL. FOR CLEAN COOKSTOVES, http://cleancookstoves.org/technology-and-fuels/stoves/index.html [https://perma.cc/H44V-9EJJ].

pollution.[25] In the years since, governments, NGOs, and companies—primarily in developed countries—have provided scientists and engineers with substantial funding to cultivate this technology.[26] Enthusiasm has only increased with hopes that these cookstoves could lead to more efficient fuel use and therefore help to mitigate climate change.[27] In 2010, the United Nations initiated the largest and most dedicated effort, the Global Alliance for Clean Cookstoves (GACC).[28] This NGO aims to increase the development and uptake of clean cookstoves by using a public-private partnership model. It promotes development through large- and small-scale grants to producers as well as the promise of carbon offsets to donors.[29] GACC and its partners also work with communities in the recipient countries to teach them about the benefits of clean cookstoves and encourage adoption of these technologies.[30] Overall, the idea is to create a global market with local flavor for this socially and environmentally important innovation. However, as already noted, clean cookstoves have seen limited success. Part of the resistance, this article suggests, is due to the initiation and development of this technology by engineers and policymakers in the developed world who operate within a dominant approach to innovation that is described in further detail below.

II. OUR DOMINANT APPROACH TO INNOVATION

Over the last century, policymakers and innovators have converged on what this article characterizes as a "dominant approach to innovation" to produce and promote science and technology in the public interest. This dominant approach emphasizes both a linear model of innovation and an assumption that the best way to promote innovation in the public interest is through the marketplace. The linear model

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[25] Tania Urmee & Samuel Gyamfi, *A Review of Improved Cookstove Technologies and Programs*, 33 RENEWABLE & SUSTAINABLE ENERGY REVIEWS 625, 626 (2014).

[26] *Our Accomplishments*, GLOB. ALL. FOR CLEAN COOKSTOVES, http://cleancookstoves.org/about/how-we-work/our-accomplishments.html [https://perma.cc/2HVR-CKUL].

[27] *See* Carrie M. Lee et al., *Assessing the Climate Impacts of Cookstove Projects: Issues in Emissions Accounting*, 1 CHALLENGES SUSTAINABILITY 53, 54 (2013); C. Venkataraman et al., *The Indian National Initiative for Advanced Biomass Cookstoves: The Benefits of Clean Combustion*, 14 ENERGY FOR SUSTAINABLE DEV. 63, 64–65 (2010).

[28] GLOB. ALL. FOR CLEAN COOKSTOVES, FUELING MARKETS, CATALYZING ACTION, CHANGING LIVES: PHASE 1 2010–2014, at 1, 4 (2014), http://cleancookstoves.org/binary-data/RESOURCE/file/000/000/283-1.pdf [https://perma.cc/4GUD-V735].

[29] *See id.* at 3, 14–18.

[30] *Behavior Change Communication*, GLOB. ALL. FOR CLEAN COOKSTOVES, http://cleancookstoves.org/market-development/demand-creation/behavior-change-communication.html [https://perma.cc/8LPE-D8CX].

assumes that technological development follows a straightforward, unidirectional process from invention to diffusion and that the first stage—invention—is the primary driver.[31] The market orientation assumes that a robust and largely unfettered marketplace stimulates innovation, and focuses on the volume and pace of innovation. It assumes further that all innovative activity is in the public interest. In this context, the public interest is often defined in terms of more technologies as well as economic growth.[32] With more technologies, markets will expand, which will create both new jobs and new consumption, eventually lifting the fortunes of everyone. And while new technologies may be too expensive for some at first, prices will eventually go down, and everyone will benefit.[33] Indeed, to the extent that governments consider the types of technologies produced, the accessibility or availability of these technologies, or the extent to which technological innovations reflect local or global public concerns, they do so only on occasion and in retrospect, after there has been a clear "market failure."[34] If a new medicine deemed essential to public

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[31] *See generally* Benoît Godin, *The Linear Model of Innovation: The Historical Construction of an Analytical Framework*, 31 SCI. TECH. & HUM. VALUES 639, 655–56 (2006); Trevor J. Pinch & Wiebe E. Bijker, *The Social Construction of Facts and Artefacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other*, 14 SOC. STUD. SCIENCE 399, 404–06 (1984). On the linear model, see DANIEL SAREWITZ, FRONTIERS OF ILLUSION: SCIENCE, TECHNOLOGY, AND THE POLITICS OF PROGRESS (1996).

[32] *See generally* SHOBITA PARTHASARATHY, PATENT POLITICS: LIFE FORMS, MARKETS, AND THE PUBLIC INTEREST IN THE UNITED STATES AND EUROPE (2017) (on the politics of defining the public interest in technology, and specifically patent policy); SAREWITZ, *supra* note 31 (on the shortcomings of assuming that more innovation will always be in the public interest); DAVID C. MOWERY & NATHAN ROSENBERG, TECHNOLOGY AND THE PURSUIT OF ECONOMIC GROWTH (1989) (questioning the utility of the dominant approach to innovation for producing economic growth); Stephen Hilgartner, *Intellectual Property and the Politics of Emerging Technology: Inventors, Citizens, and Powers to Shape the Future*, 84 CHI.-KENT L. REV. 197, 197 (2009) (on the assumptions and public values embedded in the dominant approach to technological development).

[33] The availability of new products stimulates both the development of new industries, and therefore new jobs, but also new markets for selling these products. The jobs produced by the creation of new industries also provide individuals with the income to purchase new technologies. But as these technologies remain on the marketplace (and in some cases, as their patents expire), more competitive technologies become available and the costs of all of these goods go down. *See generally* JACOB SCHMOOKLER, INVENTION AND ECONOMIC GROWTH 2–5 (1966) (on how consumer demand shapes invention, availability, and diffusion); Richard R. Nelson, *The Simple Economics of Basic Scientific Research*, 3 J. POL. ECON. 297, 302–03 (1959); W.W. Rostow, *The Stages of Economic Growth*, 12 ECON. HIST. REV. 1 (1959) (on how societies transform through the availability of technologies as well as economic growth).

[34] *See generally* Francis M. Bator, *The Anatomy of Market Failure*, 72 Q.J. ECONOMICS 351, 356–57 (1958); SAREWITZ, *supra* note 31 (on why governments should be more mission-oriented in their science and technology policies); Hilgartner, *supra* note 32 (on how policymakers, especially in the United States, do not critically consider the moral or social dimensions of a technology when encouraging its development).

health is priced too high, for example, governments may create special funds to make it more widely available to poorer communities, or occasionally intervene to eliminate the supplier's monopolistic advantages, thus allowing others to manufacture the technology at a competitive price.[35] Alternatively, they may try to create special research opportunities to address serious public problems, from infectious disease to climate change.[36] Nevertheless, by and large, market mechanisms are seen as the best way to stimulate innovation in the public interest.

Overall, the dominant innovation approach is reflected in the policies and practices of governing institutions, and in the relationships between universities, industry, and the government, in the developed world. Market forces and the purported benefits of technologies shape the work of both patent offices and regulators designed to assess the utility, risks, and side effects of pharmaceuticals.[37] Some of these countries, including the United States, have passed laws that encourage commercialization of the government-funded research that takes place inside universities.[38]

This approach also ultimately shapes understandings of what innovation and innovative work are, how innovation promotes the public interest, and what kinds of people and policies are necessary to produce and promote innovation. Here, the innovation process usually starts with policymakers, entrepreneurs, and innovators focused on generating large amounts of funding for science and engineering work.[39] They have the training, social networks, and access to funding that are necessary to produce the technologies that policymakers

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[35] The most famous example of this is U.S.-based President's Emergency Plan for AIDS Relief, initiated in 2004. *See* Ellen 't Hoen et al., *Driving a Decade of Change: HIV/AIDS, Patents, and Access to Medicines for All*, 14 J. INT'L AIDS SOC'Y 1, 5 (2011). Reluctant to allow the generic production of retro-viral medications to fight AIDS, or to force producers of these AIDS medications to license their patents to ultimately lower prices, the U.S. government purchased these medications and donated them to patients in the developing world. *See id.* 1–2, 5.

[36] *See*, *e.g.*, NELLY OUDSHOORN, THE MALE PILL: A BIOGRAPHY OF TECHNOLOGY IN THE MAKING (2003) (on a rare, mission-oriented approach to solving a gap in technological development, specifically for a male contraceptive).

[37] *See generally* PARTHASARATHY, *supra* note 32 (on how a market-shaping approach in the United States and a market-making approach in Europe have influenced patent systems in the two jurisdictions); ARTHUR A. DAEMMRICH, PHARMACOPOLITICS: DRUG REGULATION IN THE UNITED STATES AND GERMANY (2004) (on how markets help to shape pharmaceutical regulation in the United States and Germany).

[38] *See generally* PHILIP MIROWSKI, SCIENCE-MART: PRIVATIZATING AMERICAN SCIENCE (2011); ELIZABETH POPP BERMAN, CREATING THE MARKET UNIVERSITY: HOW ACADEMIC SCIENCE BECAME AN ECONOMIC ENGINE (2012).

[39] *See generally* DANIEL S. GREENBERG, THE POLITICS OF PURE SCIENCE (1999).

argue will improve citizens' lives.[40] Indeed, scientists and engineers are seen as the primary innovators. GACC and similar efforts clearly embody this model; GACC has raised over four hundred million dollars to establish partnerships with nonprofit institutions and private entities who conduct technical research and manufacture clean cookstoves.[41]

This approach conceptualizes innovation as tangible, standardizable, usually high-tech, and patentable objects ripe for the global marketplace. Only easily standardizable technologies can achieve the economies of scale needed for such markets to work. In addition, patents and patent systems play a central role, further defining our understandings of innovation as new and not obvious.[42] Indeed, patents have been central to innovation systems for over a century, based on the idea that exclusive market control over an invention for a limited period of time (now twenty years) is the best incentive to innovate.[43] This understanding of innovation reinforces the idea that innovators are highly technically trained scientists and engineers, who are invariably men.[44] Clean cookstoves fit this model, and GACC expends tremendous funding and effort on how to bring cutting-edge scientific and technical knowledge to their development and design. It further encourages cookstove producers to apply for patents on their technologies to enhance their market positions. In turn, the nonprofit and private entities developing these technologies publicize the number of patents they have received on the GACC website.[45] GACC also participates in the

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[40] *Id.*; SAREWITZ, *supra* note 31 (on how government, especially in the United States, emphasizes how science and technology will necessarily produce public benefit).

[41] *See* GLOB. ALL. FOR CLEAN COOKSTOVES, FIVE YEARS OF IMPACT 2010–2015, at 9 (2015), http://cleancookstoves.org/binary-data/RESOURCE/file/000/000/406-1.pdf [https://perma.cc/H69M-BHMS].

[42] In the United States and Europe, for example, patents are issued for inventions deemed to be novel, non-obvious, useful (in Europe this is defined as industrial applicability), and sufficiently described in the patent itself. For the U.S. patent code, see 35 U.S.C. §§ 102, 103, 111 (2012). For the European Patent Convention, which governs European patent law, see European Patent Convention (EPC) arts. 52, 54, 57, 78 (2016).

[43] *See generally* PARTHASARATHY, *supra* note 32 (on the history of modern patent systems).

[44] *See generally* ATTILA BRUNI ET AL., GENDER AND ENTREPRENEURSHIP: AN ETHNOGRAPHICAL APPROACH (2014); J. LEWIS, BARRIERS TO WOMEN'S INVOLVEMENT IN HACKSPACES AND MAKERSPACES 3 (2015), http://access-space.org/wp-content/uploads/2015/10/Barriers-to-womens-involvement-in-hackspaces-and-makerspaces.pdf [https://perma.cc/WBP2-SNCC]; Gry Agnete Alsos et al., *Gender and Innovation: State of the Art and a Research Agenda*, 5 INT'L J. GENDER & ENTREPRENEURSHIP 236 (2013); Jennifer Hunt et al., *Why Are Women Underrepresented Amongst Patentees?* 42 RES. POL'Y 831, 831 (2013).

[45] *See e.g.*, *Xunda Science & Technology Group Co., Ltd*, GLOB. ALL. FOR CLEAN COOKSTOVES, http://cleancookstoves.org/partners/item/21/583 [https://perma.cc/E9UA-4Y3Q].

commodification of carbon, offering its donors carbon credits for participating in the clean cookstove effort.[46]

While GACC assumes that markets are necessary to produce innovation in the public interest, the clean cookstove markets it has produced are not simple. First, GACC has created two markets. One is for the clean cookstoves themselves. GACC invests its own money, and encourages and coordinates others—in both the private and public sector—to invest as well.[47] As noted above, it encourages cookstove producers to apply for patents on their technologies to enhance their market positions.[48] The second market is for carbon credits, which can also be interpreted as an innovation.[49] In the carbon credit market, governments and companies in the developed world receive carbon credits if they donate to clean cookstove efforts in the developing world and these cookstoves are used.[50]

Finally, the dominant approach sees all innovation as overwhelmingly beneficial (or at least value-neutral), and thus considerable effort is spent educating laypersons about the benefits.[51] Furthermore, any controversy or resistance is seen as irrational and emotional.[52] The dominant approach assumes that communities lack the knowledge and expertise to help themselves, and instead puts them in the position of needing help not only from outsiders but also technical elites.[53] Indeed, GACC and its partners work with communities in the recipient countries to teach them about the benefits of clean cookstoves

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[46] GLOB. ALL. FOR CLEAN COOKSTOVES, CLEAN COOKSTOVES AND FUELS: A CATALOG OF CARBON OFFSET PROJECTS AND ADVISORY SERVICE PROVIDERS 1 (2014), http://cleancookstoves.org/binary-data/RESOURCE/file/000/000/381-1.pdf [https://perma.cc/37N8-VQVR].

[47] GLOB. ALL. FOR CLEAN COOKSTOVES, *supra* note 28.

[48] *See* Hilgartner, *supra* 32, at 201–02, 12.

[49] *See generally* Yasser Bhatti, *What Is Frugal, What Is Innovation? Towards a Theory of Frugal Innovation* (Oxford Centre for Entrepreneurship & Innovation, Working Paper, 2012), https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2005910.

[50] Kamilla Karhunmaa, *Opening Up Storylines of Co-benefits in Voluntary Carbon Markets: An Analysis of Household Energy Technology Projects in Developing Countries*, 14 ENERGY RES. & SOC. SCI. 71 (2016).

[51] *See generally* Andrew C. Stirling, *From Enlightenment to Enablement: Opening Up Choices for Innovation*, *in* THE INNOVATION FOR DEVELOPMENT REPORT 2009–2010: STRENGTHENING INNOVATION FOR THE PROSPERITY OF NATIONS (Augusto López-Claros ed., 2010) (on the assumption that innovation is value-neutral, and that citizens are irrational if they oppose it); MELISSA LEACH AND JAMES FAIRHEAD, VACCINE ANXIETIES: GLOBAL SCIENCE, CHILD HEALTH AND SOCIETY (2007); SAREWITZ, *supra* note 31 (on the rationality of citizen opposition to technology).

[52] *See generally* William Leiss, *Three Phases in the Evolution of Risk Communication Practice*, 545 ANNALS AM. ACAD. POL. & SOC. SCI. 85, 86, 88–90 (1996); Hilgartner, *supra* 32, at 201–02.

[53] *Behavior Change Communication*, GLOB. ALL. FOR CLEAN COOKSTOVES, http://cleancookstoves.org/market-development/demand-creation/behavior-change-communication.html [https://perma.cc/3N95-TMW6].

and to encourage them to adopt these technologies.[54] In sum, within this dominant approach, average citizens are seen as lacking the formal training to undertake innovation efforts themselves and, as such, are simply consumers of technologies produced by intellectual elites.

III. CHALLENGES TO THE DOMINANT APPROACH

The dominant approach to innovation described above has provoked considerable criticism. Some scholars argue that a market orientation does not necessarily produce innovation that is beneficial to the public.[55] Instead, this orientation tends to yield technologies that wealthier populations will purchase, rather than products that address societal needs.[56] The strong intellectual property regimes associated with the dominant approach to innovation have also been found to stifle research and, on some occasions hurt, access to potentially life-saving technologies.[57] Finally, because scientific, technological, and economic elites are the central participants in the dominant approach to innovation, the technologies produced tend to reflect their worldviews and concerns.[58] Climate change mitigation may take precedence over neighborhood health and safety worries, and new and complex technologies—that are patentable—may look better than adjustments to old ones. These concerns are particularly salient in the context of international development, where intended users are quite far from those funding, developing, and distributing innovation—in terms of spatial distance and, even more so, in terms of economic and social circumstances.

A. Alternative Approaches to Developing Technology

Governments, NGOs, and innovators focused on international development have critiqued, and tried to address the problems with, the dominant approach to innovation in a variety of ways. Some have challenged the deep-seated market

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[54] *Id.*

[55] Patrice Trouiller et al., *Drug Development for Neglected Diseases: A Deficient Market and a Public-Health Policy Failure*, 359 LANCET 2188, 2189–90 (2002).

[56] *Id.* at 2191.

[57] *See generally* MIROWSKI, *supra* note 38 (on how the modern patent system, especially in the United States, has hurt the scientific research enterprise); PARTHASARATHY, *supra* note 11 (on how the U.S. patent system has helped to constrain access to medical technology).

[58] *See generally* STEVEN EPSTEIN, INCLUSION: THE POLITICS OF DIFFERENCE IN MEDICAL RESEARCH (2007).

orientation and its consequences for the shape and availability of innovation by encouraging the development of alternative intellectual property regimes. This includes prize competitions that offer innovators large financial rewards if they make significant progress in a socially or environmentally important area and also gives them the option of letting the findings remain in the public domain (i.e., not applying for patents or maintaining trade secrets).[59]

Others have challenged the linear model by taking lay knowledge much more seriously. They try to make the technological development, design, and distribution process more democratic and appropriate for local circumstances by involving average citizens in these early stages.[60] They hope that this will ultimately produce technologies that are more useful to, and will be more easily accepted by, publics especially in the developing world because these publics participated in the innovation process. In citizen juries, one popular method, representative members of the public learn about the details of proposed technologies, including their potential benefits and risks, over the course of multiple sessions and have the opportunity to ask questions and consider whether and how such technologies can achieve citizen interests and broader social goals.[61] These efforts usually culminate in a recommendation from the citizen panel about whether and how to move forward.[62] These efforts have achieved some success. In India and South Africa, for example, they have been deployed to facilitate decision making on issues ranging from strategies for climate adaptation, to the availability and regulation of genetically modified crops.[63]

In 2001, the government of Andhra Pradesh, a state in southern India, along with NGO and university-based facilitators,

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[59] *See e.g.*, William A. Masters, *Research Prizes: A Mechanism to Reward Agricultural Innovation in Low-Income Regions*, 6 J. AGROBIOTECHNOLOGY MGMT. & ECON. 71, 71 (2003).

[60] Daniel J. Fiorino, *Citizen Participation and Environmental Risk: A Survey of Institutional Mechanisms*, 15 SCI. TECH. & HUM. VALUES 226, 229–30 (1990); Sarah R. Davies & Cynthia Selin, *Energy Futures: Five Dilemmas of the Practice of Anticipatory Governance*, 6 ENVTL. COMM. 119, 121–23 (2012).

[61] *See generally* David Dunkerley & Peter Glasner, *Empowering the Public? Citizens' Juries and the New Genetic Technologies*, 8 CRITICAL PUB. HEALTH 181, 182–83 (1998).

[62] *See, e.g.*, Paola Mosconi et al., *Cystic Fibrosis: To Screen or Not to Screen? Involving a Citizens' Jury in Decisions on Screening Carrier*, 18 HEALTH EXPECTATIONS 1956, 1957–58 (2014).

[63] *See, e.g.*, TOM WAKEFORD, ACTIONAID CITIZENS' JURY INITIATIVE: INDIAN FARMERS JUDGE GM CROPS 3 (2000), https://www.actionaid.org.uk/sites/default/files/doc_lib/citizens_jury_initiative.pdf [https://perma.cc/Y5MB-ZJ6L]; Alex Aylett, *Conflict, Collaboration, and Climate Change: Participatory Democracy and Urban Environmental Struggles in Durban, South Africa*, 34 INT'L J. URB. & REGIONAL RES. 478 (2010).

convened a citizens jury for small and marginal farmers to help develop a twenty-year vision for food and agriculture.[64] After multiple days of discussion with experts from multiple fields and subsequent deliberation, the participants issued policy recommendations that emphasized self-reliance and community control over agriculture.[65] Efforts like these, however, are somewhat limited in their scope, and they are usually ad hoc and connected to a specific technological intervention. Furthermore, the scope of the discussion is invariably defined in advance of the citizen deliberation, limiting public input.[66] Indeed, these initiatives tend to focus on technological questions posed by outsiders rather than social concerns of interest to local communities.[67] In other words, they explore whether and how a particular technological intervention can be useful and integrated into a particular context, rather than investigating the needs and concerns of the local community on a broader scale and then exploring what kinds of technological interventions might be developed to address them.

The "appropriate" or "pro-poor" technology approach represents another attempt to bring local citizens into the innovation process to maximize uptake as well as public benefit, especially in the developing world.[68] It also challenges the dominant approach's focus on new and high-tech innovation. Emerging first in the 1970s, this movement advocated development projects that focused on "small scale, energy efficient, environmentally sound, and labor intensive" interventions that were "controlled by the local community."[69] Advancement was not simply a matter of bringing inventions designed for the developed world into the developing world, they contended; rather, technologies had to be built with the local consumer and context in mind.[70] The movement has instigated programmatic shifts among NGOs and development agencies,

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[64] MICHEL P. PIMBERT & TOM WAKEFORD, PRAJATEERPU: A CITIZENS JURY/SCENARIO WORKSHOP ON FOOD AND FARMING FUTURES FOR ANDHRA PRADESH, INDIA 1, 1 (2002), http://pubs.iied.org/pdfs/9135IIED.pdf [https://perma.cc/MD3N-S2N8].

[65] WAKEFORD, *supra* note 63, at 4–6.

[66] *See generally* Michel Callon & Vololona Rabeharisoa, *The Growing Engagement of Emergent Concerned Groups in Political and Economic Life: Lessons from the French Association of Neuromuscular Disease Patients*, 33 SCI. TECH. & HUM. VALUES 230, (2008); Jason Chilvers, *Deliberating Competence: Theoretical and Practitioner Perspectives on Effective Participatory Appraisal Practice*, 33 SCI. TECH. & HUM. VALUES 155, 177–78 (2008).

[67] WAKEFORD, *supra* note 63, at 3, 10; Aylett, *supra* note 63 (on how participatory approaches have been used in the innovation process in the developing world).

[68] *See generally* LUCENA ET AL., *supra* note 9; FIELD GUIDE TO APPROPRIATE TECHNOLOGY (Barrett Hazeltine & Christopher Bull eds., 2003).

[69] FIELD GUIDE TO APPROPRIATE TECHNOLOGY, *supra* note 68.

[70] *Id.*

who now consider local concerns and uptake more seriously in the development process.[71] Consider, for example, the Arsenic Biosand Filter Project. Scientists at the Massachusetts Institute of Technology developed this filter to "remove arsenic and pathogens from tubewell water," for use in rural Nepal.[72] They saw it as particularly promising because they could train local labor to build the technology and use locally available materials.[73] The project was only partially successful, however; evaluators found that the technology failed on multiple occasions because local users had trouble constructing the technologies themselves and protecting some of its components from environmental pollutants.[74] The unfamiliarity of the technology made it difficult for local citizens to use. In sum, citizens struggled to build and use this technology in part because outside scientists and engineers played the primary role in design and development.[75] And even in cases where citizen needs and values seem to drive the innovation process, outside NGOs, entrepreneurs, and policymakers take the lead in the design and development process.[76] This approach does little to empower local populations on a long-term basis, and instead continues the dependence of citizens from the developing world on governments and NGOs in the developed world.

B. Grassroots Innovation

The focus on high technology sectors and the development of modern innovation systems have led governments and NGOs to forget that innovative ideas, and even technological development, are not solely the province of those with science and engineering training. To address these concerns, in recent years scholars, policymakers, and even the media have begun to highlight

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[71] *See generally* Robert Chambers, *The Origins and Practice of Participatory Rural Appraisal*, 22 WORLD DEV. 953 (1994).

[72] TOMMY NGAI & SOPHIE WALEWIJK, THE ARSENIC BIOSAND FILTER (ABF) PROJECT: DESIGN OF AN APPROPRIATE HOUSEHOLD DRINKING WATER FILTER FOR RURAL NEPAL ii (2003), http://web.mit.edu/watsan/Docs/Other%20Documents/KAF/Ngai Walewijk-%20ABF%20Report2003.pdf [https://perma.cc/F5DE-Z3ZW].

[73] *Id.*

[74] Heather A. Lukacs, From Design to Implementation: Innovative Slow Sand Filtration for Use in Developing Countries 61 (June 2002) (Masters Thesis, Massachusetts Institute of Technology), http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.582.1924&rep=rep1&type=pdf [https://perma.cc/V6BE-ZUZ5].

[75] *See generally* Adrian Smith, *The Alternative Technology Movement: An Analysis of Its Framing and Negotiation on Technology Development*, 12 HUM. ECOLOGY REV. 106 (2005).

[76] *See generally* FIELD GUIDE TO APPROPRIATE TECHNOLOGY, *supra* note 68.

grassroots innovation efforts.[77] For the purposes of this article, "grassroots innovation" is defined as usually low-tech, low-cost, and small-scale technologies generated by poor and marginalized populations who usually have a limited education.

These initiatives are important from a development perspective, because when those with few resources innovate, they are likely to build technologies that will benefit both themselves and their neighbors.[78] After all, given their marginalized position, these innovators are unlikely to be driven by hopes of participating in the global marketplace. Consider the example of Arunachalam Muruganantham, an Indian man who dropped out of school at the age of fourteen, who learned upon marriage about the difficulties that poor and rural Indian women face during their menstrual cycles.[79] These women are forced to use cloth rags, which are often unsanitary and can be quite debilitating.[80] So, Muruganantham worked with his wife and mother to develop an indigenous version of the sanitary pad, as well as an indigenous method of production.[81] Driven by curiosity and a desire to help his wife, as well as other women, he risked his reputation and marriage, and invested his own time and resources to make sanitary pads available and affordable to women in his community.[82] Ultimately, he developed a product and created a market that both commercial and government entities would not.

This kind of grassroots innovation can also emerge at the community level.[83] STS scholar Roopali Phadke brought to light the case of the Baliraja Memorial Dam, located in Maharashtra state in central India.[84] Farmers and social activists mobilized to convince engineers and the government to build a

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[77] *See, e.g.*, Yudhijit Bhattacharjee, *How an Indian Innovator Reverse-Engineered the Making of Sanitary Pads*, N.Y. TIMES (Nov. 10, 2016), http://www.nytimes.com/interactive/2016/11/13/magazine/design-issue-sanitary-pads-india.html [https://perma.cc/2C59-FWPE]; *see generally* Anuja Utz & Carl Dahlman, *Promoting Inclusive Innovation*, *in* UNLEASHING INDIA'S INNOVATION: TOWARD SUSTAINABLE AND INCLUSIVE GROWTH 105, 112 (Mark A. Dutz ed., 2007).

[78] Anil K. Gupta, *Innovations for the Poor by the Poor*, 5 INT'L J. TECH. LEARNING INNOVATION & DEV. 28, 29 (2012).

[79] Vibeke Venema, *The Indian Sanitary Pad Revolutionary*, BBC (Mar. 4, 2014), http://www.bbc.com/news/magazine-26260978 [https://perma.cc/C6JH-M48C].

[80] *Id.*

[81] *Id.*

[82] *Id.*; *see also* Bhattacharjee, *supra* note 77. Both of these articles suggest that Muruganantham was motivated simply by the desire to help his wife and other women in his community.

[83] *See generally* Adrian Smith et al., *Grassroots Innovation Movements: Challenges and Contributions*, 63 J. CLEANER PRODUCTION 114, 114 (2014).

[84] Roopali Phadke, *Assessing Water Scarcity and Watershed Development in Maharashtra, India: A Case Study of the Baliraja Memorial Dam*, 27 SCI. TECH. & HUM. VALUES 236, 236 (2002).

dam to serve irrigation and domestic needs in the villages of Balawadi and Tandulwadi.[85] But these community members did more than convince technical and government elites to invest in the technology. They conducted scientific investigations themselves, organized local science fairs to investigate village waterways, wells, and irrigation facilities, and surveyed local elders about past water conditions.[86] Then they set up a Council for Drought Eradication, which decided that the local water shortage could be solved by constructing a "people's dam."[87] Finally, they convinced engineers not only to help them, but to design a dam that considered citizens' knowledge, was made from locally available materials, and employed local workers in its construction.[88]

Despite the successes in these two cases, they were still ad hoc and dependent on the energy and initiative of the participants involved. In addition, they do not address some of the systemic problems with the dominant innovation approach which constrains the likelihood that these kinds of innovation will gain attention and be fostered. In the next section, the article explores two Indian efforts to address these problems through systemic interventions to stimulate grassroots innovation: The Honeybee Network (THN) and the Self-Employed Women's Association (SEWA).

IV. GRASSROOTS INNOVATION SYSTEMS IN INDIA

India is a particularly rich site for this study because it has a long history of supporting grassroots innovation. It is home to Ayurveda and yoga, centuries-old indigenous knowledge systems designed to improve well-being and health.[89] Moreover, its national identity is tied to this concept. Starting in the late nineteenth century, in response to forced dependence on British colonists for food, textiles, and other essential goods, India's first nationalist movement emphasized *swadeshi*, or indigenous production, as the path to independence.[90] Nationalists boycotted British clothes and tried to revive

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[85] *Id.* at 244.

[86] *Id.* at 243.

[87] *Id.* at 244.

[88] *See id.* at 245.

[89] Ayurveda is a medical system with roots in ancient Hindu texts, known as the Vedas. Therapies are often based on complex herbal compounds or surgery. Similarly, yoga is also a healing system based in Hindu Vedic texts and is often incorporated into Ayurvedic therapies. *See generally* DEBIPRASAD CHATTOPADHYAYA, HISTORY OF SCIENCE AND TECHNOLOGY IN ANCIENT INDIA: ASTRONOMY, SCIENCE AND SOCIETY (1996).

[90] Lisa N. Trivedi, *Visually Mapping the "Nation": Swadeshi Politics in Nationalist India, 1920–1930*, 62 J. ASIAN STUD. 11, 11 (2003).

domestic manufacturing processes and products.[91] The movement evolved over the next five decades, and "homespun" innovation and industry became a central platform in Mahatma Gandhi's independence fight in the 1940s.[92] Once the country gained independence in 1947, it implemented trade policies that fostered the development of strong indigenous industries in textiles, automobiles, and pharmaceuticals.[93]

Meanwhile, for centuries Indians have valorized the development of frugal, innovative, and makeshift technological solutions, which has even generated a Hindi word: *jugaad*.[94] The most well-known example is an improvised vehicle (titled, in fact, *Jugaad*) powered with diesel engines usually used for agricultural irrigation pumps.[95] Although it cannot go faster than sixty kilometers an hour, its low cost (approximately eight hundred dollars) has made it a primary means of transport for many rural Indians.[96] This history and ideology make India a particularly conducive site for new systems designed to foster grassroots innovation, but many other developing countries have similar indigenous knowledge traditions and would likely benefit from systemic efforts to foster grassroots innovation.[97]

A. The Honeybee Network

The Honeybee Network (THN), which now includes both NGOs and a government bureaucracy, is a result of India's grassroots innovation legacy. It was first envisioned in the 1980s by Indian Institute of Management Professor Anil Gupta. After doing research on innovation and entrepreneurship for years, Gupta realized that innovation takes place everywhere,

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[91] *Id.* (on the Swadeshi movement including the British boycott).

[92] *See generally* DAVID ARNOLD, EVERYDAY TECHNOLOGY: MACHINES AND THE MAKING OF INDIA'S MODERNITY (2013).

[93] *See generally* BHUPESH BHANDARI, THE RANBAXY STORY: THE RISE OF AN INDIAN MULTINATIONAL (2005); LISA TRIVEDI, CLOTHING GANDHI'S NATION: HOMESPUN AND MODERN INDIA (2007); INDIA'S REFORMS: HOW THEY PRODUCED INCLUSIVE GROWTH (Jagdish Bhagwati & Arvind Panagariya eds., 2012).

[94] *See generally* VINAY DABHOLKAR & RISHIKESHA T. KRISHNAN, 8 STEPS TO INNOVATION: GOING FROM JUGAAD TO EXCELLENCE 6 (2015); Ramendra Singh et al., Jugaad—*From 'Making Do' and 'Quick Fix' to an Innovative, Sustainable and Low-Cost Survival Strategy at the Bottom of the Pyramid*, 8 INT'L J. RURAL MGMT. 87 (2012).

[95] Pankaj Sekhsaria, *The Making of an Indigenous STM: Technological Jugaad as a Culture of Innovation in India*, *in* STUDIES OF NEW AND EMERGING TECHNOLOGIES: SHAPING EMERGING TECHNOLOGIES: GOVERNANCE, INNOVATION, DISCOURSE 137, 139 (Kornelia Konrad et al. eds., 2013).

[96] MARKETING MANAGEMENT 441 (V.S. Ramaswamy & S. Namakumari eds., 5th ed. 2013).

[97] *See generally* DAYO OLOPADE, THE BRIGHT CONTINENT: BREAKING RULES AND MAKING CHANGE IN MODERN AFRICA (2014); CORI HAYDEN, WHEN NATURE GOES PUBLIC: THE MAKING AND UNMAKING OF BIOPROSPECTING IN MEXICO (2003).

including among those who lack formal technical education or easy access to the organizations or capital that customarily foster technological development.[98] He sought to create structures that would encourage this innovation, among what he called "knowledge-rich and economically poor" communities, because he thought it might be the most useful in producing both inclusive growth and environmentally sustainable solutions for India.[99] First, he created NGOs in his home state of Gujarat, in northwestern India, to identify and work with grassroots innovators and to disseminate their ideas among the community and among entrepreneurs.[100] In 2000, the Indian government invested in Gupta's approach and established the National Innovation Foundation (NIF), building on the successes of the original NGOs.[101] With approximately one hundred employees and dozens of individual and organizational partners across India, the NIF is designed to "strengthen the grassroots technological innovations and outstanding traditional knowledge."[102] Its mission is to help India become a creative and knowledge-based society by expanding policy and institutional space for grassroots technological innovators."[103] To date, THN has identified over 200,000 technologies developed by grassroots innovators across the country including the low-cost windmill discussed in further detail below.[104] Overall, the grassroots innovation system built by THN incorporates some aspects of the dominant approach to innovation but also deviates from it in important ways.

THN's process begins with scouting and identification. The NIF and its associated NGOs do this by sponsoring exhibitions and competitions, and by placing advertisements in local newspapers across India.[105] In addition, every year a small

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[98] Gupta, *supra* note 78, at 29–32; Anil K. Gupta, *Tapping the Entrepreneurial Potential of Grassroots Innovation*, 11 STAN. SOC. INNOVATION REV. 18, 18–19 (2013).

[99] Anil K. Gupta et al., *Networking Knowledge-Rich, Economically Poor People*, *in* INFORMATION AND COMMUNICATION TECHNOLOGY IN RURAL DEVELOPMENT ch. 8 (Subhash Bhatnagar & Robert Schware eds., 2000), http://documents.worldbank.org/curated/en/543321468338476969/pdf/389200Info0and1cation0200001PUBLIC1.pdf [https://perma.cc/PZ49-46S7].

[100] Anil K. Gupta, *From Sink to Source: The Honey Bee Network Documents Indigenous Knowledge and Innovations in India*, 1 INNOVATIONS 49, 50–51 (2006).

[101] *See generally* Anil K. Gupta et al., *Mobilizing Grassroots' Technological Innovations and Traditional Knowledge, Values and Institutions: Articulating Social and Ethical Capital*, 35 FUTURES 975, 983–84 (2003).

[102] Interview with Staff of Nat'l Innovation Found., in Ahmedabad, Gujarat, India (Dec. 17, 2015).

[103] *About Us*, NAT'L INNOVATION FOUND.–INDIA, http://nif.org.in/aboutnif.php [https://perma.cc/EP25-X74X].

[104] *Id.*; *see infra* notes 114–115 and accompanying text.

[105] Interview with Staff of Nat'l Innovation Found., *supra* note 102.

group of staff and volunteers takes a one to two week walk in a different part of the country, to meet with grassroots innovators directly.[106] The idea, as one NIF staff member told me, is to "meet them where they are."[107] This is true not just literally, but also figuratively. Rather than assuming that innovators have formal training in science or engineering and participate in the high-tech economy, THN sees itself as facilitating a more citizen-driven understanding of innovation. This differs from the scouting and identification practices used in the dominant approach to innovation in a few ways. Whereas the dominant approach assumes that large amounts of capital (whether offered by government research funding agencies or through industry) and the promise of patent rights are needed to stimulate innovation, THN assumes that innovation is already happening and its job is to identify, facilitate, and promote it. Also, the dominant approach defines innovators and innovative work quite narrowly by comparison, generally limiting its focus to scientists and engineers performing high-tech work. This is even true for the new "maker spaces" that have emerged around the world. While maker spaces are often framed as democratizing innovation, many observe that the participants are experienced male hobbyists who invariably rely on high-tech equipment.[108]

After the initial scoping process, the NIF assesses eligible inventions according to their potential to help the local community, their environmental sustainability, and the feasibility of further development.[109] This explicit focus on public benefits and sustainability distinguishes the NIF not only from dominant systems which assume the benefits of innovation, but also from the *jugaad* mindset that invariably focuses on short-term and makeshift solutions. Based on this assessment, NIF chooses a subset of these technologies to develop further.[110] Its staff then works with grassroots innovators to conduct extensive field-testing, to test the technology's effectiveness, and then refine inventions to comply with existing laws and regulations.[111] In order to do this, it may partner with the Indian government's laboratories.[112] Rather than being focused solely on generating ideas and technologies of their

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106 *Id.*
107 *Id.*
108 LEWIS, *supra* note 44, at 5–6.
109 Interview with Staff of Nat'l Innovation Found., *supra* note 102.
110 *Id.*
111 *Id.*
112 *Id.*

own, then, as they do when they follow the dominant innovation system approach, these government laboratories play a service role in The Honeybee Network.[113] Consider, for example, THN's investment in a low-cost windmill. Two farmers from the Indian state of Assam, who have only a high school education, were unsatisfied by the existing technologies available to irrigate their fields for winter crops.[114] Existing hand pumps required a great deal of time and labor (and had negative health impacts), while pumps powered by a diesel engine were costly and had negative environmental impacts. So, these farmers developed a windmill made of tin sheets and supported with bamboo rods, costing approximately 120 USD.[115] THN helped the farmers secure an Indian patent, develop their technology so that it could be adapted to different types of farming practices, and conduct multiple field trials to gauge the technology's effectiveness.[116]

THN also works with the innovator to disseminate his technology. This includes, but is not limited to, patenting and commercialization; to date, THN has helped inventors file over seven hundred Indian patents.[117] In cases where commercialization seems appropriate, THN negotiates, on the innovator's behalf, with companies who have manufacturing and distribution capacity.[118] It sees itself playing a supportive role, ensuring that the inventor's terms are met. These negotiations differ from those common to dominant innovation systems, which focus on maximizing scalability of the technology, market share, and ultimately revenue. The system assumes that if market potential is maximized, the community will benefit through increased access to the technology. In THN's system, however, the focus is on producing social benefit and ensuring that the inventor benefits. As a result, the terms of these agreements invariably include direct benefit-sharing provisions with the local community. The inventors of the low-cost windmill, for example, used a portion of their earnings to donate their windmills to needy farmers.[119]

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[113] *Id.*

[114] Kavita Kanan Chandra, *Barefoot Innovators*, TRIBUNE (Dec. 7, 2014), http://www.tribuneindia.com/news/spectrum/barefoot-innovators/13900.html [https://perma.cc/KHY6-XUAQ].

[115] *Id.*; Anil K. Gupta, *What Can We Learn from Green Grassroots Innovators: Blending Reductionist and Holistic Perspectives for Sustainability Science*, http://anilg.sristi.org/wp-content/Papers/What%20can%20we%20learn%20from%20green%20grassroots%20innovators.pdf [https://perma.cc/49TE-MFJ3].

[116] Interview with Staff of Nat'l Innovation Found., *supra* note 102.

[117] *About Us*, *supra* note 103.

[118] Interview with Staff of Nat'l Innovation Found., *supra* note 102.

[119] *Id.*

If the corporate sector decides not to invest, this does not doom the technology. This is, of course, another departure from the dominant innovation approach. THN usually takes on the dissemination responsibilities instead. They may work with local factories to manufacture the invention on a small scale, or they may help the innovator disseminate knowledge about her work in surrounding communities so that others can develop it themselves or invent beyond it.[120] Regardless, they always translate information about the inventions they support into India's many languages and dialects, as a means of continuing to engage a larger and more diverse public in the innovation process.[121] It is important to THN to disseminate information about the invention as widely as possible, whether or not it is commercialized.[122] This does not just give other citizens the opportunity to develop the innovation themselves. It may inspire them to innovate as well. The ultimate goal of this system is to empower the innovative work of the average citizen, in order to encourage technological development that may be more useful to economically disadvantaged communities while also demonstrating the value of grassroots knowledge to scientific, technological, and economic elites.

B. The Self-Employed Women's Association

The Self-Employed Women's Association, or SEWA, a large and internationally known NGO that represents women in the informal economy, has also created an alternate innovation system designed to valorize the knowledge of its members while encouraging innovative efforts to improve their lives.[123] Established in 1972, it is a trade union representing almost a million "poor, female self-employed women workers," many of

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[120] *Id.*

[121] Gupta et al., *supra* note 99, at 88–89.

[122] *Id.* at 92.

[123] *About Us: Introduction*, SELF EMPLOYED WOMEN'S ASS'N, http://www.sewa.org/About_Us.asp [https://perma.cc/2T9B-KQ6C]. Many scholars, including those from India and Western countries, have written about SEWA's work. *See, e.g.*, KALIMA ROSE, WHERE WOMEN ARE LEADERS: THE SEWA MOVEMENT IN INDIA (1992) (on the history and politics of the Self-Employed Women's Association); Renana Jhabvala, *Self-Employed Women's Association: Organising Women by Struggle and Development*, *in* DIGNITY AND DAILY BREAD: NEW FORMS OF ECONOMIC ORGANIZATION AMONG POOR WOMEN IN THE THIRD WORLD AND THE FIRST 114 (Sheila Rowbotham & Swasti Mitter eds., 1993); Rekha Datta, *From Development to Empowerment: The Self-Employed Women's Association in India*, 16 J. POL. CULTURE & SOC. 351, 351 (2003); M. Kent Ranson et al., *Making Health Insurance Work for the Poor: Learning from the Self-Employed Women's Association's (SEWA) Community-Based Health Insurance Scheme in India*, 62 SOC. SCI. & MED. 707 (2006).

whom work in the informal economy across India.[124] This includes home-based workers, street vendors, construction laborers, and rag pickers.[125] Built upon an explicitly Gandhian ideology like THN, it strives for women's empowerment by helping them gain full participation and security in the labor force.[126] In some important ways, however, it differs from THN's approach. Perhaps most importantly, it challenges the focus on tangible objects as technologies and innovates by providing of a variety of services including health and childcare, legal aid, communication, and banking.[127]

SEWA initiates its innovative efforts with a grassroots approach, asking a representative subset of its large membership about its needs and concerns.[128] SEWA conducts surveys on a particular topic, such as health and hygiene, and then gathers additional information through focus groups following an approach they developed while doing participatory rural appraisals starting in the 1970s.[129] Whereas the dominant approach tends to still rely on technical and economic elites to drive innovation, SEWA has instituted stable and frequent opportunities for citizen engagement that then drives the direction of its innovation. The ideas generated by SEWA's membership may require the development of new material objects, new social services, or both. Interestingly, unlike THN, SEWA does not classify this kind of work as innovation, but rather as providing a social service.[130] This resonates with women's traditional reluctance to see themselves as innovators, or as doing innovative work.[131] To them, innovation itself is gendered masculine. Yet, as argued above, innovation can be both social and technical, and there is no a priori reason to focus only on material objects. If we see innovation as focused on stimulating new ideas and technologies that produce social benefit, then much of SEWA's work clearly fits.

If SEWA decides to pursue development of a material object, it usually requests assistance from outside innovators to

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[124] Ranson et al., *supra* note 123, at 709.

[125] *See* Kamala Kanta Mohapatra, *Women Workers in Informal Sector in India: Understanding the Occupational Vulnerability*, 2 INT'L J. HUM. & SOC. SCI. 197, 197–99 (2012).

[126] *See generally* Datta, *supra* note 123; *About Us: Introduction*, *supra* note 123.

[127] *See generally* Ranson et al., *supra* note 123.

[128] *See generally* ROSE, *supra* note 123; Jhabavala, *supra* note 123, at 114.

[129] ROSE, *supra* note 123, at 45–46.

[130] Interview with Staff of Self-Employed Women's Ass'n, in Ahmedabad, Gujarat, India (Dec. 16, 2015).

[131] *See* Wendy Faulkner, *The Technology Question in Feminism: A View from Feminist Technology Studies*, 24 WOMEN'S STUD. INT'L F. 79, 79 (2001); LEWIS, *supra* note 44, at 8–12.

build prototypes.[132] This assistance may come from NGOs. For example, THN has linked SEWA to grassroots innovators identified through its programs to assist in the development of fuel-saving devices.[133] Alternatively, SEWA may receive help from government laboratories and factories.[134] Once a prototype has been developed, SEWA members test it exhaustively for quality and reliability as well as the ease of integration into existing social systems.[135] This departs from the dominant approach because users guide the development process starting from the early stages. SEWA then works with its technical liaisons to incorporate their members' feedback on the technology and repeats this process until the members are satisfied.[136] SEWA also tries to bring its members directly into the development and manufacturing process, so they can learn how to work with the relevant equipment and expand their own knowledge and expertise.[137] It does this with the explicit goal of increasing the self-reliance of these women so that they not only inspire and inform the development of these technologies but also develop the skills to build the technologies themselves.[138] SEWA's leadership also recognizes, as this article describes in more detail below, that it may need to build new social systems—like new social services or infrastructure—to accommodate the new material object.[139] In this way, it is clear that the organization sees innovation similarly to STS scholars, as sociotechnical systems that require both technical and social work.

Consider SEWA's efforts to develop low-cost but high-quality sanitary pads. In surveys and focus groups, its members identified this as a serious need because it was hurting their participation in the labor force.[140] As discussed above, women used cloth rags during menstruation, which they had to replace constantly and ultimately confined them to their homes. While they were aware of Muruganantham's efforts, SEWA staff observed that his products were not of high enough quality.[141] In addition, because menstruation is a taboo subject in India, they worried that women would still be reluctant to purchase even these low-cost sanitary pads from market stalls or pharmacies

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132 Interview with Staff of Self-Employed Women's Ass'n, *supra* note 130.
133 *Id.*
134 *Id.*
135 *Id.*
136 *Id.*
137 *Id.*
138 *Id.*
139 *Id.*
140 *Id.*
141 *Id.*

staffed by men.[142] In other words, simply designing a new material object with the needs of these women in mind would not ensure its uptake. With assistance from factories owned by the Indian government's Council for Scientific and Industrial Research (CSIR), SEWA developed prototypes which it tested in the community.[143] This testing led to multiple changes in the width, length, and absorbency of the pads, as well as adding "wings" to the sides. These changes to the technology required changes to the machinery, which CSIR was willing to do.[144] Women also learned how to operate the machinery used to make the sanitary pads.[145]

But perhaps most importantly, SEWA also had to invent a new distribution system, as women would still be unable or too shy to purchase the pads from men.[146] So, it expanded the scope of its Rudi Multi-Trading Company (Rudi). SEWA established Rudi in 2007 as a rural distribution network that would connect rural producers and consumers, but also help producers invest in new technologies to improve their businesses.[147] In this distribution system, producers reach consumers through a network of female intermediaries (who are SEWA members), who sell producers' goods door-to-door to (predominantly) female consumers and also inform consumers about newly available products.[148] While the vast majority of goods sold through this network are agricultural products, from almonds to lentils, SEWA's leadership realized that it could be expanded to include sanitary pads and therefore provide women with a modicum of privacy. This approach seems to have worked, and women are now purchasing sanitary pads through Rudi at 1.5 rupees ($0.02) per pad.

Including sanitary pads in SEWA's distribution system highlights how it engages in innovation quite differently from the dominant approach, and even THN. While it produces new material objects in familiar ways, its novel distribution system and the importance of including sanitary pads in that system again call attention to the constraints of the dominant approach to innovation. While innovators and policymakers tend to focus on material objects, SEWA's work with sanitary pads reminds us that not only does innovation not have to be

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142 *Id.*
143 *Id.*
144 *Id.*
145 *Id.*
146 *Id.*
147 *Id.*
148 *Id.*

solely material and mechanical, but also often requires accompanying innovative social practices.

SEWA also treats women, even those with limited education and resources, as primary innovators. They are involved at every stage of the process, and their knowledge is treated as central to technological development. And, by including them in the manufacturing process, SEWA may also be helping women see themselves as innovative and capable of producing new ideas and material objects themselves.

Investing in SEWA's approach may not lead as directly to a post-carbon world as clean cookstoves or solar lamps. Indeed, SEWA members are unlikely to raise climate change as a pressing issue in their daily lives. And even when they do express interest in cheaper and cleaner cookstoves that reduce carbon emissions, they are frustrated when these technologies break down easily or require specialized knowledge to build.[149] In addition, their husbands are often uninterested in investing in a technology that they do not believe will help them in a significant way.[150] If SEWA members are given the tools and opportunity to develop solutions to their own problems, however, the technologies they develop seem much more likely to be successful.

CONCLUSION

This article has argued that in order to stimulate the development of effective technologies for a post-carbon world, innovators and policymakers must envision innovation as part of sociotechnical systems. These sociotechnical systems include not only particular norms, values, and assumptions regarding the given technology's use, but also particular assumptions about innovation and how it should be fostered. Further, it has suggested that the technologies usually produced as part of international development efforts are tied to a dominant approach to innovation, which explains some of the resistance they encounter when they are transferred to the developing world. To address this resistance, policymakers should consider and amplify indigenous grassroots innovation systems envisioned in developing countries. THN and SEWA, both based in India, a country with a long legacy of fostering grassroots innovation, provide analytically rich alternatives to our dominant innovation approach.

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[149] *Id.*

[150] *Id.*

The cases of THN and SEWA should redirect global attention away from high-tech interventions that aim to promote the public interest, and toward low-tech solutions produced by those without extensive formal education. Furthermore, THN and SEWA remind us that technological development is not only about manufacturing novel material objects, it is also about constructing complementary social systems.

In order to make a technology truly work, as we saw in the case of SEWA's sanitary pads, we must develop systems that take seriously the worlds in which the objects are embedded, and accommodate different processes and definitions of innovation. Indeed, THN and SEWA remind us that innovators are not just scientific, technical, and economic elites. Poor and rural citizens—even those who lack formal education and technical training—can not only clearly articulate their needs vis-à-vis innovation, but also build technologies that may simultaneously achieve personal, societal, and global ambitions. To understand whether and how global priorities might be achieved on a local level, policymakers must consider both the necessities of the community and the potential for local laborers to serve as grassroots innovators.

In developing alternative systems, we must rethink traditional roles in the innovation system. We tend to focus on laboratories as spaces where scientists have the freedom to test their new theories, and factories as locations where qualified engineers develop technologies demanded by the marketplace. But in both of the systems described here, citizens offered the innovative ideas, and laboratories and factories simply tested or developed them further, thereby inverting the traditional relations of power. THN and SEWA also went out of their way to solicit innovative ideas and technologies from disadvantaged and typically marginalized populations, and then vetted them with the public interest explicitly in mind.

These cases should also encourage systems that reconsider the importance of markets—and market incentives—in serving the public interest. THN and SEWA focused on innovation that explicitly privileged affordability, accessibility, and sustainability, rather than simply defining the public's interest in terms of incentives to innovate and fostering economic growth on a broad scale, as we usually do. THN and SEWA also emphasized wide dissemination, even if this required creative distribution efforts or limits to commercialization. Of course, this is more interventionist, and therefore looks quite different from the patent systems supported by the dominant approach. Overall,

however, these examples should lead policymakers, NGOs, scientists, and engineers to fiercely challenge assumptions about which policies, institutions, and participants are necessary to promote innovation that is in the public's best interest.

Finally, these alternatives should compel those focused on international development to disaggregate public interest at the global and local levels as they assess potential technological interventions and the systems that produce them. There are certainly some goals that are in the global community's best interest—including mitigating climate change—but it is also important to consider whether the efforts for achieving these goals send citizens down dubious technological paths that are without local support and do not consider the locality's best interests.

Certainly, there are some limitations to incorporating a sociotechnical systems approach to our understanding of innovation. It is emphatically more labor intensive, requiring policymakers and NGOs to understand the critical importance of social and political context as they build not only technologies, but also systems to promote innovation. It may lead to technological development that supports local concerns at the expense of global goals, like a post-carbon world. Finally, given the strength and penetration of the global marketplace, it is difficult to imagine that multiple indigenous innovation systems can ever overcome the dominant innovation approach. In particular, technologies that operate across countries, or at least require international standardization, will likely continue to be driven by the dominant approach. If more attention is paid to the development of indigenous innovation systems, however, then citizens in developing countries will be able to take greater strides not only towards self-sufficiency but to a post-carbon world.