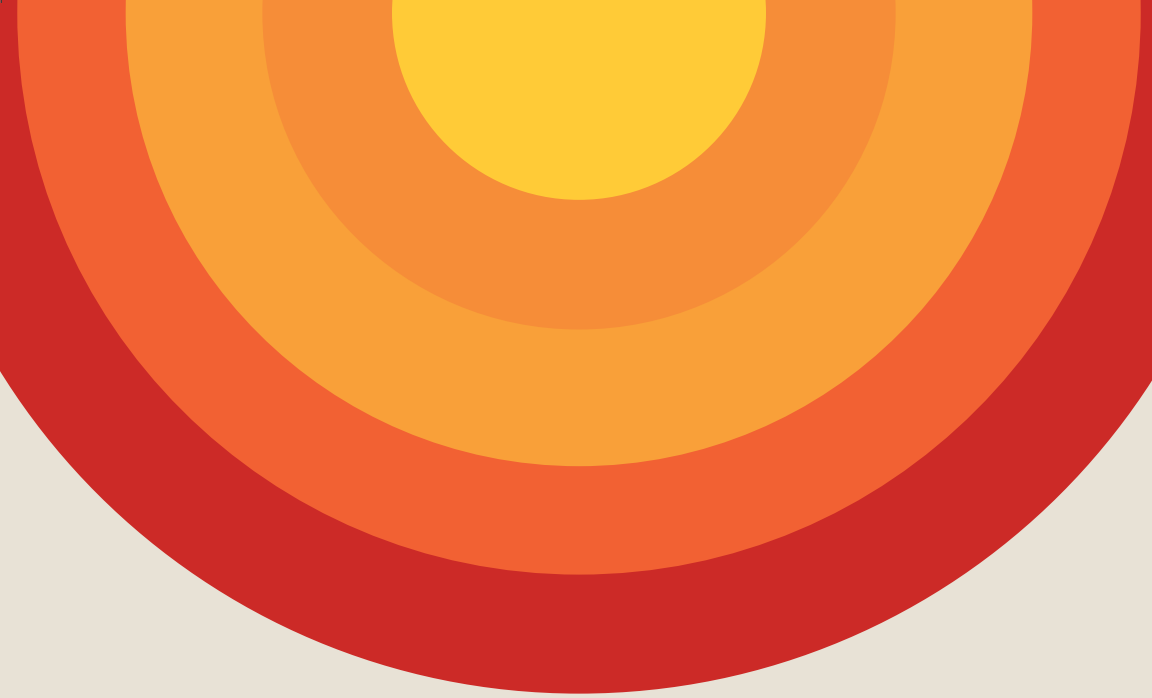

THE WEIGHT OF LIGHT

A Collection of Solar Futures

Joey Eschrich and Clark A. Miller, Editors
Ruth Wylie and Ed Finn, Project Directors

The Weight of Light:
A Collection of Solar Futures

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ASU Center for Science and the Imagination
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The Weight of Light: A Collection of Solar Futures.

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In memory of Yaron Ezrahi, 1940-2019,
who illuminated the centrality of imagination
and fiction in the project of democracy.

O you hastening light!
O the sun of the world will ascend, dazzling,
and take his height—and you too will ascend;

O so amazing and so broad! up there resplendent,
darting and burning;

O prophetic! O vision staggered with weight of light!

—Walt Whitman, in "Apostroph,"
Leaves of Grass, 1860

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Credits

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About the Project

This collection was inspired by a simple question: what would a world powered entirely by solar energy look like? In part, this question is about the materiality of solar energy—about where people will choose to put all the solar panels needed to power the global economy. It's also about how people will rearrange their lives, values, relationships, markets, and politics around photovoltaic technologies. The political theorist and historian Timothy Mitchell argues that our current societies are *carbon democracies*, societies wrapped around the technologies, systems, and logics of oil.[1] What will it be like, instead, to live in the *photon societies* of the future?

To probe these questions, the Center for Science and the Imagination[2] hosted the Solar Futures Narrative Hackathon on April 30 and May 1, 2018, in Tempe, Arizona, in collaboration with the Quantum Energy and Sustainable Solar Technologies Engineering Research Center[3] and the School for the Future of Innovation in Society[4]. The event brought together science fiction authors, visual artists, experts in fields ranging from public policy to electrical engineering, and talented student researchers to create technically grounded, inspiring visions of a future

shaped by a transition to clean, plentiful solar energy.
Participants divided into four teams, each focused on a different scenario for the future of solar energy in terms of two controlling variables: geography and size. *Geography* denotes the split between urban and rural; that is, whether solar infrastructure is integrated into densely populated areas, where demand is concentrated, or sited in sparsely populated areas further from major cities. *Size* differentiates between large-scale, centralized facilities for generating energy and small-scale, decentralized infrastructure spread across a multitude of sites.

Depending on the group members' interests and the needs of their future vision, the teams also selected secondary variables to integrate into their work*: aesthetics, efficient vs. abundant deployment, extraction & supply chains, ownership & governance, storage,* and *waste & recycling.*

In person during the workshop, and virtually in the weeks following the gathering, each team produced a short story set in the near future, a work of visual art that represents a key moment or theme from the story, and one or more essays that scrutinize the technical, cultural, and political issues that undergird these visions of the future, considering how we could get from here to there, and what signposts and obstacles we might meet along the way.

Narrative Hackathons are intensively collaborative, structured as a series of short interactive sessions with clear goals and deliverables. Our teams oscillated between small-group brainstorming, large-group presentations, cross-group feedback, revisions and refinement, and individual working time throughout the two-day event.

In the wake of the event, the teams continued their conversations and worked with editors to sharpen and finalize their stories, visual art, and essays.

Our goal for this project is to reveal the richness and diversity within the arena of futures built upon the promise of clean, plentiful energy. The transition to solar and other clean renewable sources isn't just a light switch that we can flip; it will be messy, and it will involve consequential decisions about design, structure, democratic process, the character of the relationship between humans and the environment, and much more. In this collection, we aim to depict these multifarious solar futures, and the choices that shape them, as exciting spaces for imagination, exploration, deliberation, debate, and even a dash of adventure.

To see full-color versions of the visual art, and to download and read this collection in different formats, visit https://csi.asu.edu/books/weight.

Timothy Mitchell, Carbon Democracy: Political Power in the Age of Oil (New York: Verso), 2011.

2. https://csi.asu.edu/

3. https://www.qesst.org/

4. https://sfis.asu.edu/

Designing in Sunlight

By Clark A. Miller, Joshua Loughman, Wesley Herche, Dwarak Ravikumar, Joey Eschrich, Ruth Wylie, Ed Finn, Christiana Honsberg, and Stuart Bowden

Sunlight bathes the Earth in enough energy in a day for 10 years of global energy consumption.

Solar photovoltaics is the fastest-growing and least expensive energy technology on the planet.

It's also one of the most flexible. Solar panels are found on satellites, suburban rooftops, Ikea stores, university stadiums, and parking garages, not to mention giant power plants on retired farmlands or in the desert.

This combination of low cost and high flexibility presents a unique opportunity—and a profound design challenge.

People who design and build solar systems confront a plethora of design options for the future of solar energy.

These design options are, in part, technical.

Where do we deploy solar, in what kinds of systems, requiring what kinds of data and information, posing what kinds of challenges for the electricity grid, etc.?

Solar design options are also social, economic, political, and environmental.

Who will own the panels and derive economic benefit? How will their deployment be governed, and according to what rules? Where will we get the materials to build them? How will those materials be disposed of when the panels no longer function? Which kinds of lands or spaces will we use to generate solar energy?

How do we decide which designs to go with?

Energy choices are often thought of in terms of solar vs. coal or renewables vs. fossil fuels.

In the future, they're likely to be solar vs. solar.

Solar vs. solar, when all is said and done, isn't just about which technology to choose but also what kind of society to build.

Solar design choices are the central focus of this book.

The stories, essays, and artwork in this book explore the future of solar energy as a problem in the design of future photon-based societies.

They prompt, we hope, a more sustained dialogue about human futures in the shadow of solar energy.

Solar energy is growing rapidly. The world added more new solar energy in 2017 than any other source of electricity. In total, in 2017, humans built 100 Gigawatts (GW) of new solar power plants. For comparison, the Palo Verde nuclear power plant in Phoenix, Arizona, one of the world's largest, is 4 GW. Think about that for a moment.

In one year, people all over the globe installed the equivalent of 25 new, large-scale nuclear power plants' worth of solar energy.

Looking forward, the growth of solar energy should continue to accelerate. Saudi Arabia recently announced plans to build 200 GW of solar power plants by 2030, enough to cover an area the size of Chicago. In their 2018 Global Energy Perspective, consultants at McKinsey estimated that 64% of worldwide energy investments over the next three decades will be in solar energy, for a total of 7.7 TW by 2050.[1] That's roughly 2000 new nuclear power plants the size of Palo Verde, or the equivalent area of 35 cities the size of Chicago.

Global growth in solar energy is being driven by steep, steady, and persistent price declines. Recent contracts for solar energy in Mexico and Saudi Arabia set record lows for the price of electricity. On average, U.S. families pay roughly 10 cents for each unit of electricity; these new plants generate it at less than 1.8 cents. No other form of electricity is price-competitive with solar at the moment. In Arizona and New Mexico, recent contracts have priced solar at roughly 2.3 cents. By 2030, McKinsey predicts that, in Britain, not exactly known for its sunshine, it will be cheaper to build new solar power plants than to operate existing natural gas plants. As a result, as reported in the 2018 World Energy Investment report from the International Energy Agency, global investments in new fossil fuel infrastructure are quickly falling.[2]

The world is also experiencing a sea change in global policy responses to climate change and environmental degradation. In 2017, dozens of major world cities committed to meeting their obligations to the Paris Agreement in order to limit climate change to 1.5 degrees Celsius. Two U.S. states, Hawaii and California (as well as numerous cities) have passed legislation requiring their

states to derive 100% of their electricity from renewable energy by the middle of this century. Corporate America is moving even more quickly to green its energy systems. Germany has famously launched an Energiewende to power the entire country with 60% renewable power by 2050, and Mexico unveiled a new Ley de Transición Energética in 2015. These initiatives, combined with other policy actions to limit carbon emissions, such as countries setting dates for banning sales of internal-combustion engines, will put pressure on fossil energy and accelerate solar energy. It's entirely conceivable that the buildout of solar energy will be even faster than McKinsey anticipates.

While these facts make it tempting to adopt a "let's just sit back and watch the show" mindset, these transformations in global energy markets raise a variety of important questions about the design of solar energy futures. Some of the most obvious include: Where and how will solar energy systems be deployed, e.g., on buildings or in the desert? What impacts will they have on those spaces and how they are used? Will solar energy disrupt or reinforce existing energy technologies and markets? Will the resulting power plants be ugly or beautiful? Who will own them? Who will regulate them? What kinds of jobs will they create, and for whom? How will solar systems be integrated into broader systems of power, transportation, manufacturing, and computing, not to mention food and water systems? How will they shape global patterns of security, power, and wealth?

The answers to these questions are not foregone conclusions. They are design choices. The choices we consider, the criteria we use to evaluate them, and the options we choose will have enormous

implications for our future—as will the design choices we choose not to reflect on.

Century ago, the people of the United States and other countries faced very similar questions surrounding the birth of modern electricity systems. Who would own the production of power? Who would control or regulate it? What form would energy markets take? The designs they created, largely organized around centralized, monopoly urban electric utilities, served by large, coal-fired power plants, have dominated the electricity sector ever since. They have profoundly shaped contemporary ways of living, working, and playing, enabling the transformation of agricultural societies, bound to the patterns of day and night, into global, 24/7/365 cultures that thrive on the hum of industrial and, today, increasingly, digital life.

With new forms of energy, however, come new design options. Today's energy design choices will shape the future as much as yesterday's choices shaped the present.

This book is a prompt. We are trying something new. Our goal is not to predict the future but to open it up as a design space. Our hope is that these stories, essays, and artwork will stimulate and expand our imagination about what kinds of choices are possible in designing the future of solar-powered societies, and why those choices matter. The works are thus a form of design fiction.[3]

Through the genre of science fiction, the stories function as a

form of technology assessment.[4] They help readers imagine what it might be like to inhabit different futures. They explore design alternatives, both for technology and society. They engage what technologies might do and what they might mean for people across the planet.

We have chosen not to tell just one story about the future of solar energy but rather many. Each is set in a rich social milieu in which solar energy has taken a different path. The stories are science fiction, but we have taken very few liberties with either technologies or societies. The stories were informed by both engineers and social scientists, working collaboratively with writers and artists. We have tried hard not to create either utopias or dystopias. The stories do not present ideal visions of what solar-powered futures should or should not look like. Nor are we recommending any of these futures. They are just speculative possibilities. The actual design of desirable solar-powered futures is up to our readers, not us.

Our experiment in speculative energy fiction is informed by a long legacy of scenario analysis: an array of strategies for imagining multiple plausible futures by exploring the potential pathways along which futures might unfold. Energy scenarios in particular have a long and rich history. As early as the 1970s, Shell Oil used formal scenario analysis to explore both possible futures of energy and futures for the world more broadly that would coexist with them. Today, scenarios are widely produced and used by energy firms, university researchers, nongovernmental organizations such as the World Energy Council, Greenpeace, and the World Bank, and government agencies such as the German Federal Ministry for the Environment and the National Renewable Energy Laboratory. Remarkably few of these scenarios, however, have asked more than how much solar energy the world will deploy and on what timetable.

Our goal, by contrast, is to significantly expand the range of solar design choices envisioned and considered in energy planning. By opening up the design imagination, we aim to encourage reflection on the potential pathways, intended and unintended consequences, and social outcomes of solar energy development, and hence to allow judgments about the desirability and undesirability of competing solar futures.

In thinking about the future of energy design, it is useful to keep three simple ideas in mind.

First, the future is open to design. Not infinitely, of course, nor necessarily easily. Design always operates within limits. People inhabit complex networks and systems in which worldwide trends flow from the collective consequences of billions of individual choices. The design of the future doesn't always lie, therefore, within the purview of a single individual or institution. This complexity does not obviate human responsibility for the future, however. There is no preordained technological path. Ultimately, the choices that we all make do matter in shaping the futures we arrive in.

Second, technologies are always the product of our societies. There are many different ways to make computers—mainframes, desktops, laptops, smartphones, and more. There are many different ways to integrate computers into larger digital networks and systems. And there are many different ways to put those computers to use to create new futures for people and businesses. So, the design choices that innovators, consumers, and regulators make matter for how technology turns out. The evolution of digital technologies has taken different forms and paths in the United States, Europe,

China, India, Africa, and elsewhere. Notwithstanding the rhetoric of Silicon Valley, computers have not flattened the world, and variation persists in the kinds of digital landscapes that people inhabit around the globe. The same is likely to be true of solar energy technologies in the future.

Third, our societies are a product of our technologies. Not in some deterministic sense: technology does not drive history. People always drive history. They make and use technologies. Nonetheless, technologies enable people to think and act in new ways. As people take advantage of those opportunities, they reshape their values and behaviors, their relationships to one another, and their institutions. In the process, they reshape societies.

The future of technology and society are inseparably woven together. The ways that we choose to design technologies both shape and get shaped by our choices about how to design societies. Technological futures both create and respond to distributions of power and wealth, cultural values, and social inequalities.

Even though we often pretend otherwise, the design of energy systems is never just about technology; it is always also about the design of human futures.

This implies that we design society when we design and organize solar panels.

What are some of the ways that this integration of social and technological design happens?

One example: when we design solar systems, we design not only where the panels are built but also who owns and derives revenue from them.

The same technology—a two-foot by three-foot photovoltaic (PV) panel—can be deployed in a wide variety of social and market arrangements. In Arizona alone, we have at least seven different market configurations for deploying solar panels. We've built giant power plants in the desert, owned by utilities or independent power companies. Commercial businesses have put solar panels on their roofs. Governments have built publicly owned systems. And we've put solar panels on suburban rooftops. Homeowners own some of these rooftop systems, banks and corporations own others, and still others get leased from Elon Musk. Which design wins out will have profound social, economic, and political implications for the future of Arizona.

A typical PV panel today costs about $250. Over its 25-year lifetime, it will generate electricity perhaps worth $1000. That's not a bad investment: roughly a 5% annual rate of return. The question of ownership ultimately boils down to who nets the resulting $750 in profit.

Historically, energy companies and governments have owned most energy assets, netting the vast majority of energy profits and transforming them into some of the world's largest and richest organizations. Will that be true in the future? Do we want it to be? Enabling individuals or communities to own their own power could upend existing patterns of wealth and inequality in the world.

Another example: the linkage between energy and security. Humanity has a long and bloody history of fighting global wars over energy resources. Will the wars of the future be fought over sunlight? Fortunately, solar power is widespread across the face of the

planet. As recent attacks make clear, however, energy systems face significant risks of cyberterrorism, and highly concentrated solar facilities could become future military targets.[5]

How do we identify the full array of social and technological design choices available to us as designers of solar energy futures? And how can we make these choices in a more informed fashion?

We argue for an anticipatory design approach that uses storytelling and narrative to open up the imagination to questions about the human dimensions of technological innovation.[6] The goal is to explore ahead of time what future design choices might be available and how those choices might matter for different groups in society.

This kind of anticipatory design approach is, from our perspective, critical to avoiding the kinds of design flaws that have emerged in the construction of other recent technologies.

Facebook didn't have to design a system that enabled Russian hackers to attack U.S. elections. Apple could have designed iPhones that didn't addict us. Artificial intelligence algorithms needn't replicate human biases. The internet didn't have to be designed without built-in cybersecurity. Yet all four have recently occurred in the design of digital technologies.

We believe that taking an anticipatory design approach to solar energy technologies will help to improve the societies we build through solar energy innovation.

At the heart of the anticipatory design fiction work of this book are three core sets of design questions. The authors and teams that built the stories considered a number of potential design variables (for a full list, see the "Solar Design Choices" section of this book, immediately after this essay). Of those, three emerged as particularly salient for the stories in this collection.

1) World-building and landscapes: What kinds of technological worlds and societies and landscapes will we design for our children via new solar energies? Where will solar power plants be deployed, what will they look like, how big will they be, who will live next to them, and what kinds of lives will they experience? What criteria should we use to decide which aspects of the solar worlds we design are desirable or undesirable?

2) Work, economy, and inequality: How will solar energy innovation transform the future of work—and of markets and the economy? How will solar economies distribute or redistribute energy wealth? Will they reinforce existing inequalities, create new ones, or contribute to ending global poverty?

3) Power and governance: Who will decide the shape of future technologies and societies? How might design decisions be made democratically? How will they feed back into the workings of democratic institutions and governance?

The stories, of course, are much richer than can be captured by these few questions. And the design options deliberated by the teams during the two days of the workshop were more complex and nuanced than even the stories capture. Fully considering solar energy design options will be an ambitious undertaking for any community. We hope that what we've done here inspires people to do that work.

Humans have long made their place in the world through the technological transformation of landscapes: dense-packed city skyscrapers, sprawling suburbs, mining zones, industrial manufacturing centers, and vast tracts of rural agricultural production. Lewis Mumford called this facet of economic development The Machine, and he lamented the extent to which societies routinely fail to reflect on the technological environments they create and inhabit.[7]

Solar energy is the next iteration of The Machine. Already, it is transforming diverse urban and rural spaces.

One of the most powerful elements of science fiction is its ability to use stories to conjure the visual imagination—to help people "see" the look and feel of future worlds. This property of science fiction derives from the way our mind processes visual information. When people look out at city skylines, snow-capped mountains, or wide-open prairies, they don't just perceive with their eyes; they also see with their imagination. They imbue vistas with meaning, value, emotion, and history—and the imaginative elements of sight inflect how the brain processes and interprets visual stimuli on the optic nerve. Language and stories connect the same circuits, using meaning, in turn, to stimulate the visual imagination.

Solar panels interrupt such vistas, both literally and figuratively. Just as solar panels collect sunlight, they collect the eye. Whether amassed by the thousands or dotting individual rooftops, solar panels draw attention to themselves, changing how people see and give meaning to urban and rural landscapes. They are new, innovative objects. They represent change. They are cultural and political symbols for progressives and conservatives alike. Their presence

in viewsheds matters; it means something. As the title of the book suggests, they have visual weight.

s in "Big Rural," by Cat Rambo. Trish has been sent to investigate vandalism at the new solar power plant she manages next door to a dusty farm town, Tierra del Rey, which is also her hometown. She stops first at an old vantage over town. So integral to her old hometown's identity that it has a name, Ojos de Amistad Lookout is a place from which Spanish conquerors once looked down on the land, and now the townspeople come to catch the region's famous sunsets. Gazing out across familiar terrain, however, Trish finds herself drawn to a vast black square: Sol Dominion I, an inky black stain of solar panels spilling across what used to be farmland outside of town. It is a blight, she discovers, as the story unfolds, that has penetrated far more than just her view of the sunset. Her family and friends feel powerless—lodged in the shadow of the enormous power plant—to prevent distant cities from transforming the very space they inhabit. So they seek to destroy the plant. It is a blight she can redeem, but only if she can persuade town leaders and her bosses at the power company to envision a different relationship between solar energy and the town's agricultural history and future.

Solar sightlines are equally central to "Divided Light," by Corey S. Pressman. Borrowing from Romeo and Juliet, the story tells the tale of two lovers, and two families, bound up in two very different visions of the future of solar energy. One family rules The Thumb: a giant solar canopy, visible from distant horizons, imposing its will on the people and lands it shades, a protector against the stark sunlight of the desert summer, and a source of almost unimaginable power for both the city and its vast plantations and water purification systems. The other family are Ramish artisans: entrepreneurial artists and engineers who craft light into powerful, personalized artifacts.

Ramish clans are decentralized, scattered across the desert. Layered into the skin, in luminescent tattoos, or carried by hand, in reed-like lanterns and batteries, Ramish devices are designed both for instrumental value, helping people create the resources necessary to survive in harsh desert environments ravaged by climate change, and as a source of profound beauty.

Brenda Cooper's "For the Snake of Power" offers a third variation on the new infrastructural realities wrapped up in solar energy. It's hard to underestimate just how vast the spatial requirements are to power the human future. An enormous amount of sunlight shines on the Earth: many times more in one year than all of the world's known fossil fuel reserves. Yet that energy is enormously diffuse. We will have to collect it where it falls. The theoretical physicist Freeman Dyson imagined encapsulating an entire star in a sphere of solar-collecting material in order to create the power necessary for interstellar civilization. We don't need that much, at least not yet, but what we do need will be visible. In this story, the form it takes is a long snake of panels, winding their way along the canals that slake Phoenix's thirst and water its grass. By shading the water, they decrease evaporation, reducing the energy required to pump water to Phoenix in the first place. It's a virtuous cycle—until a dust storm breaks the snake, then power starts to go missing, and all kinds of politics heat up. It's a powerful reminder that human societies depend deeply on their energy systems—and when those systems go awry, so too can social order.

Social order of a more intimate form is also at stake in "Under the Grid," by Andrew Dana Hudson. The only story not set in the desert, it unfolds in the midst of vibrant bottom-up community innovation in Detroit. Drawing on a metaphor of gardening, each homeowner tends her own little patch of sky, with its individually

designed and owned solar system (and who knows what else, like nests built for migrating endangered birds), in order to contribute their required share of solar energy to the city's power grid. When Ingrid's mom breaks her leg, however, and the local boys won't help out with system maintenance, the neighbors threaten to have her evicted, and Ingrid is forced to help out. It's an intricate story that highlights the complexity of the intersecting technologies, laws, and social norms that together make up the modern electricity grid, and the potential for distributed solar energy systems to further entangle that knot.

Alongside the future of technological landscapes—real or virtual—the future of work is now firmly at the center of discussions of technological innovation. Typically, the problem of technology and work is formulated in terms of whether automation will replace human labor. Will there be fewer jobs in the future, or more? That question has arisen for solar energy, and there have been various attempts to answer it—none of which are, to date, entirely satisfactory.

What is clear is that the nature of energy work will change. Coal miners will be replaced by solar system manufacturers and installers. The geography of those jobs will be different. So will their pay, their unionization, their working conditions, and their relationships to worker health.[8]

The stories in this book explore this more nuanced question of the future organization and character of work within the context of choices about how to design solar energy systems. The questions they pose are not about how many people will work in the solar industry, but who will work, where, and how, what work is required

by different configurations of solar technologies, and how the responsibilities of that work will be divided across different groups.

A great variety of work is enmeshed in the diverse solar energy systems captured in the four stories. And that work is distributed very differently across the stories' diverse inhabitants. Workers create and innovate solar systems. Other workers build, operate, and maintain them. Still others troubleshoot when they go wrong or operate the legal institutions that regulate their behavior. Some work in partnership with artificial intelligence systems.

Both "For the Snake of Power" and "Big Rural" focus on solar energy professionals working in large bureaucracies to manage enormous power systems that straddle vast distances. It is a role that sets them at odds with others in the stories who live nearby or rely on the power generated by their facilities, especially when things go wrong. "You work for power now?" Inez demands angrily of Rosa in "For the Snake of Power." It is also a familiar form of work in existing energy systems. Energy technologies are some of the world's largest systems, in terms of both the geographies they cover and the populations they serve, and the organizations responsible for them are some of the world's largest, as well.

The large size of energy systems creates and reinforces differentiated economic and cultural geographies, such as centers and peripheries, with significant disparities between them. Trish's own departure, in "Big Rural," from the small agricultural town Tierra del Rey to the Sol Dominion energy company headquarters—Are they located in Phoenix, or perhaps in Beijing?—symbolizes the cultural distance between energy systems managers and Tierra del Rey's former coal-plant and agricultural workers displaced by the new solar energy facilities. At the same time, Trish's ability to bridge that distance in the story's final moments—by envisioning a hybrid

solar-food system that empowers local agricultural innovators and workforces—suggests a form of imaginative design work that may be quite important to the future of the solar energy.

Work is also at the heart of "Under the Grid," but in a wholly different way. In a distributed energy paradigm, everyone owns their own solar systems, but they also have to maintain them. It is a challenge that has bedeviled efforts to deploy solar energy to serve rural, isolated communities in developing countries. When something goes wrong, who fixes it? "Under the Grid" also highlights the labor of social coordination required to operate decentralized socio-technological systems. Someone has to permit all of the diverse individual systems. Someone else has to make sure that all of the system owners are keeping up with their maintenance. And when that job inevitably generates conflict, someone else again has to step in to resolve the disputes.

"Divided Light" focuses less on work, although what it does suggest is interesting. The Umbra Corporation runs The Thumb, although it remains largely ancillary to the story. The reader learns only that Radrian's mother is a "VP of something-or-other" at the company. For its residents, The Thumb is less about work than about lifestyle. It's a place to live and play in comfort. The Sun Belt has never been, unlike New York, Chicago, or Silicon Valley, a place or an idea known for its economy or the forms of work and business it supports, and Shade City continues this tradition. By contrast, for the Ramish, the work of making—and of making life possible in the desert—is central to their culture, and yet it is not modern work, separate from the daily life of the household. Their daily labor includes working the land, working the technology, working the food, the water, the light. Work is ubiquitous, overlapping and blended with home and life, much as we imagine farm life and farm

work of earlier eras. The Ramish phrase "step into the light" means to take responsibility for one's own survival and thriving, and that of one's family and one's community. It is a deep responsibility that entails extensive work, but work that is of a piece with and integrated into everything that one does—not the clocking in and out of the factory laborer.

Solar energy requires work. We know that. Indeed, it requires intricate varieties of work. Opening up the design of that work raises interesting possibilities for what the future may bring—a fact that communities may want to think hard about as they anticipate the future of solar energy.

Power. Solar power. Since the late nineteenth century, when the word power first began to be used to refer to electricity, drawing on earlier notions of the power of machines to accomplish work, it has been recognized that electrical power is intimately related to political power.[9] It's easy for us, today, to understand the relationship between (electrical) energy and (political) power. After all, oil, too, is a form of power. Energy, writ large, is one of the world's largest industries. It has concentrated wealth and influence enormously in the hands of those who control it. Energy, moreover, shapes the constitutional foundations of modern societies, as the world learned in 2017-18 over the nine months that much of Puerto Rico was without electricity. Modern forms of technological life are simply not possible without modern energy systems to support them. Threats to energy security are thus threats to social and political order and stability.

It is perhaps not a surprise, therefore, that questions about the design of solar power futures inevitably also involve the design of

energy politics and governance. Hence the persistence of conflict across all four stories. Part of the focus on conflict is, of course, the nature of narrative. Good stories often involve conflict as a tool for keeping the reader's attention. More importantly for us, conflict opens up the conversation about design because it draws competing alternatives into sharp contrast and comparison. Conflict also focuses attention on the many different people involved in diverse aspects of energy systems and why each party cares about the situation at hand. In conflict, we see both why and how design choices matter. And a lot of conflict boils down to politics and power.

The conflicts are different, however, across the four stories. Politics can take many forms. We didn't design the stories that way. But it's reflective of the world all of us live in today. Across the globe, every form of energy is currently under protest, somewhere, by someone, including solar energy.

In "Big Rural," conflict occurs between city and countryside over where solar energy will be built, whether it will displace other forms of electricity generation, and who benefits from the Sol Dominion I and II power plants. In other words, it's about the distribution of benefits and burdens among diverse stakeholders.

In "For the Snake of Power," conflict occurs when the power goes out. A freak dust storm knocks out the snake, but when the power doesn't come back on, and the city faces the prospect of 120-degree temperatures without air conditioning, unrest begins to spark. And when it turns out that the blackouts aren't just a result of the accident, the staff that manages the snake has to fight the powers that be to get the electricity turned back on. In the end, it's a conflict that's partly about who benefits from the snake's power, but just as much about, in a democracy, how decisions about technologies like the snake get made.

In "Divided Light," conflict flares between two communities, each of whom has pursued a different model of how to build a photon-based society. The resulting clash of cultures is no longer just about control over technology or the wealth that flows from it, but instead about what counts as a good society. As Radrian explains,

> To my Shade-City-believer, die-hard-Umbra parents, the Ramish vision was anathema. The Ramish wanted power distributed throughout society, not concentrated in a single company or an enormous grid. They wanted to make their own food, via whatever hijacking and hacking of nature was required, not import organic produce from half a world away. Perhaps most importantly, the Ramish were evangelists, seeking to graft their vision to the soul of New Phoenix. They were a cult, stealing away Shade City youth and brainwashing the world. They didn't want Shade City to succeed or expand.

Finally, in "Under the Grid," conflict occurs inside the system, in the formal and informal governance arrangements that enable the system to operate. In this case, it's about whether or not people are living up to their civic duties, but it could just as easily be about a fight between two engineering teams over how to most efficiently operate the snake. Whether they're centralized or distributed, energy systems entail complex organizational arrangements that inevitably create internal tensions and disagreements.

The International Energy Agency estimates that it will cost something like $70 trillion to decarbonize the world's energy systems

and build a clean energy future.[10] That's an enormous investment in the human future.

For many, the only serious question is how fast we can accomplish the transition to solar energy. It's a seductive proposition. Climate change is dangerously transforming our environment. We don't have a lot of time left.

Yet, the design choices we face in constructing solar energy futures are deeply significant in their own right. We could spend $70 trillion, create an energy system powered entirely by the sun, and still fail to deliver electricity to the 1 billion people on Earth who don't currently have it. That would be among the most unethical choices ever made in the design of a new technology, whether by intention or indifference.

We could also arrive at a world in which we are building 1 TW (terawatt, a trillion watts) worth of solar energy power plants every year, each lasting for 25 years. That would entail manufacturing, putting up, taking down and either recycling or disposing of, each year, an area of solar panels eight times the size of Los Angeles. That's an enormous construction enterprise to power the planet.

Working alongside of efforts to rapidly scale solar energy to power the globe, we need a global conversation about how to design solar futures. Literally everything is at stake.

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Solar Design Choices

Geography: Where will solar energy systems be built?
There are many aspects of this choice, including the urban/rural question posed by the stories and essays in this collection. But geography is also about whether we build in deserts or on farms, everywhere or just in sunny places, on public lands or private lands, on rooftops, in parking lots, in parks, or as giant shade structures over entire cities, and much, much more.

Scale: How big will the solar systems of the future be?
Many people argue that the only financially sensible approach is to build the cheapest solar plants, which at the moment are also the largest: utility-scale projects of 10+ MW. But distributed, rooftop-scale systems of a few kW remain popular with households all over the globe and have many advantages, despite sometimes being more expensive. Rooftop systems deliver energy at the point of consumption, reducing losses from transmitting energy long distances and the costs of building and maintaining transmission lines. And many others advocate for the benefits of community-scale solar

projects, in the 1-5 MW scale, that power individual neighborhoods or small communities.

Ownership: Who will own the solar energy of the future and benefit financially?
Ownership of and financial benefit from existing energy systems tends to be highly concentrated. Solar systems are already demonstrating the viability of very different ownership models that distribute financial risks and rewards in new and innovative ways. Key questions include scale and distribution of energy ownership (potentially independent of, or intertwined with, system size and geography) and questions of public vs. private ownership.

Governance: Who will make the rules for solar energy futures?
Existing energy systems operate under a huge variety of governance models, from government-owned-and-operated models to regulated monopolies to electricity markets to internationally traded commodities. Solar could arguably easily fit into all of these options and perhaps some new ones.

Aesthetics: Can solar energy futures be made beautiful?
It's a taken-for-granted assumption of modern energy landscapes that energy infrastructures are industrial monstrosities. Where they aren't relegated to out-of-the-way locations, they are visual blights. Folks like the Land Art Generator Initiative, on the other hand, are exploring whether the future of solar energy is in tourism. Can energy also be art?

Supply Chains: Where do all those solar panels come from?
The design of the solar energy manufacturing industry, with its

factories and transportation systems, is a critical question with regard to the future of the solar energy workforce (e.g., where will the jobs be, and what kind of jobs will they be), and how its financial benefits and environmental risks are distributed. Given the scale of construction required, it's also important to consider what materials get used in manufacturing solar panels and where and how those materials are dug up and transformed into the building blocks of PV systems.

Waste: Where do all the dead solar panels go?

We currently expect that solar panels will last 25 years before needing to be replaced. Longer lifecycles may be possible in the future, but a century from now, we'll have had to figure out how to dispose of four generations of solar panels, in very high volumes. How we set up the plans to do that will have major implications for society and the environment.

Big Urban

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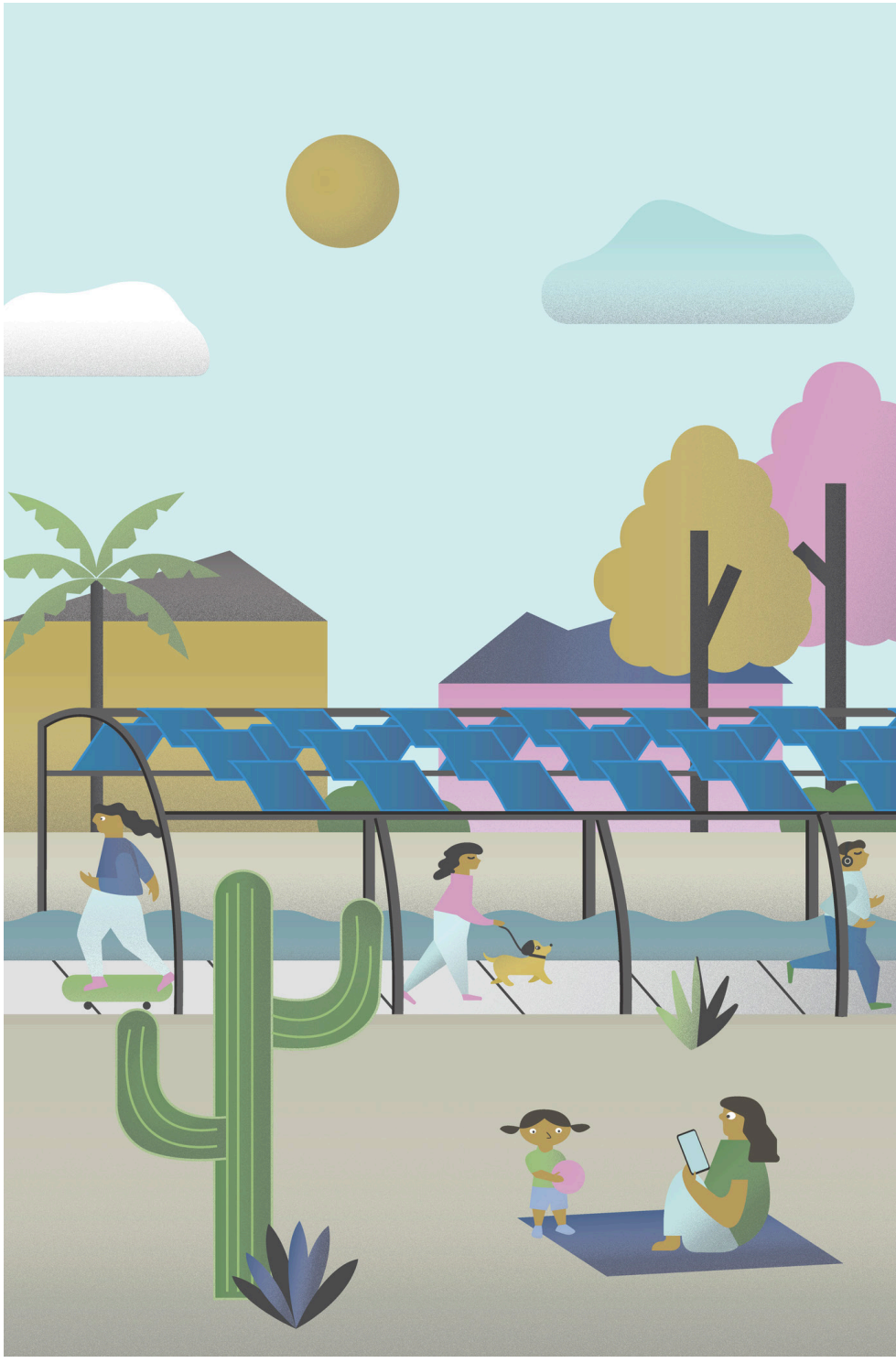

For the Snake of Power

By Brenda Cooper

Rosa rubbed at her eyes, trying in vain to focus on the map in front of her. The electronic image of the great—and greatly damaged—solar snake that covered the canals of Phoenix swam in her vision. The snake had been bruised, battered, and in a few places, actually broken by the huge dust storm that had enveloped the city three days ago. A haboob. Uncountable motes of dust carried in on a scorching wind and left behind to dim solar panels, catch in the wires that held them together, and clog the maintenance robots. Such tiny things to have done such damage. Forty-three deaths. Trees knocked down and signs ripped from the ground and hundred-year-old saguaros laid flat. But those weren't her problem. Power was.

The snake had been overengineered on purpose, built to supply the future. She'd been working with the snake's maintenance AI, HANNA, for two years now, and even with the dust and the damage, the vast, beautiful array should create enough power.

"HANNA?" Rosa addressed the AI, which listened through a button-sized speaker on her desk. "Have you figured out why the power drawdown keeps getting worse?"

Rosa had chosen an old woman's voice for the AI. It sounded calm

as it said, “Not yet. I will keep looking.”

A stray thought made Rosa tell it, “Look beyond the engineering. If you haven’t seen a problem there, then the problem is somewhere else. Power storage? Legal?”

“Is that permission?” HANNA asked.

Rosa hesitated. But HANNA wouldn’t ask if Rosa couldn’t give it permission. “Yes.”

“Logged.”

“I’m walking down to the closest break.”

“You have worked 14 hours today.”

The machine wasn’t responsible for maintenance on her. “Maybe if I see for myself, I’ll understand. Goodnight.”

“Goodnight, Rosa.”

Rosa left the building, still wearing her blue Salt River Project work shirt. A hot, dry wind created a small cloud of dust that tickled her ankles. After half an hour, Rosa spotted the snake’s glow from a block away. Its pale blue and yellow lights looked brighter than usual with the streetlights dimmed to half power.

As she stepped under the arch and onto the pathway, she startled as a maintenance robot scuttled overhead, a tiny broom stuck to one “arm” and an air puffer clenched in the other. It reminded her of a fantastical creature from fiction, half squirrel and half Swiss-army knife.

The path was busy. Two young women wearing roller skates and pushing children in carriages slowed her. Hoverboards and bicycles sped in both directions.

Her earpod pinged softly and she touched it. A newsnote, read in a flat masculine voice. “The Association of Solar Power raised rates yet again, citing a deficit of power. Brownouts are scheduled

to begin at noon tomorrow. Schedules will be posted at 7:00 a.m."

In summer, brownouts killed. She clenched her fists.

As she neared the break, the walls separating the neighborhoods from the canal looked haphazard. A bit of chain link, a makeshift wooden fence, a neat brick section, an adobe segment with the shards of glass embedded in its top glittering softly in the snake's light. Her old home. She had been gone six years. She didn't recognize the people lounging against the walls, sharing beer and listening to music. Two young men stared at her, and suddenly she wished she had changed out of her SRP shirt.

As she passed, conversations lowered or changed tenor, although no one approached.

She reached the break and stopped under it, staring up. The snake undulated throughout the city, sometimes only 20 feet above the canals and sometimes the height of a tall building, the design part art and all function. The taller loops reached for sun that buildings or bridges would block. This break was near where a segment began to rise. Three supports had come down. Solar scales had shattered on the pathway and, almost certainly, into nearby backyards. A few still dangled, askew, edges connected to the wire scaffolding that managed the panel's tilt.

The breach was serious, but a hundred yards beyond it the snake continued up toward the top of this curve, lights on, clearly working. Every two or three poles carried power and optics into underground conduits. Any break could only affect the area of the break plus two segments at worst. The snake had lost four segments of power here, but there were thousands. HANNA reported 153 segments out, which was less than 10 percent.

Tonight's low was expected to be 95, and next day's high 121. The rich often had their own systems. If not, they had cool places to go,

and transportation to power if they needed it for oxygen tanks or powered wheelchairs. The poor wouldn't even be able to run a fan.

Rosa had held her grandmother's hand when she died of heat in the power wars of '32. She had been just seven years old, sweating and miserable, her head afire with heat and dehydration, singing to her grandmother. She'd felt her grandmother's hand go limp, had seen the life fade from her smile, her cheeks, her eyes. Rosa had cried, hot and miserable, and slept with her head on her dead grandmother's chest until her father found her there an hour later.

She swallowed, able as always to feel the slip of that hand into death. Some memories burned themselves into your soul.

Steps from behind drew her out of her reverie.

"Rosa. That you? That really you?"

Although she hadn't heard it for five years, the voice was family. Home. Rosa turned and smiled. "Inez."

"You work for power now? For SR f'ing P?"

Rosa took a step back, slightly put off by the sheer press of Inez's voice, and of her body, which was bigger than she remembered, broader and more muscular. The light from the snake and the path lights combined to paint Inez's face a dull blue. "Yes."

"You going to fix this?"

"SRP is doing everything possible to restore power ..." The look on Inez's face made Rosa hear the corpspeak she was spilling out, and she stopped. Took a breath. Looked right at Inez. "If I can."

The two women stood quiet long enough for Rosa to wonder if Inez was as unsure of what to say as she was, then Inez said, "I knew you'd do okay. I'm sorry. I just didn't ... expect ... I didn't think you'd become ..."

"The enemy?" Rosa smiled. "I'm not."

Inez merely stared.

They had been good friends once. Done homework together. Skipped school together. Yet Rosa felt a distance from Inez that bothered her. “Are you okay?”

“I got two kids. Mom’s sick. Dad died.”

“I’m sorry. About the sickness. Congratulations on the kids.” She was stuttering. Was Inez married? She didn’t remember. “Sorry about your dad.”

“He was a bastard.” Inez’s shoulders relaxed a tiny bit and she smiled. “The kids are great. Lonny’s five and likes to cause trouble. His little brother, José, he’s small and smart.”

“And your mom? I remember she used to make me chipotle and chicken soup when I had a cold.” Inez’s mom, Maria, had smiled whenever Rosa ate her soup, and Rosa had felt better whenever Maria smiled. “What’s wrong with her?”

“She’s been wishing to die since dad left us. But I don’t want her to die.”

“I understand. Remember my grandmother?”

“Yes.” Inez swallowed and shifted her weight. “I came to tell you to be careful. There’s people who don’t care for SRP here. And you just raised the rates again.”

“I didn’t. Besides, SRP doesn’t set rates anymore. That’s the governor’s Association of Solar Power. The ASP. A committee.”

Inez narrowed her eyes. “People still hate SRP.”

Rosa nodded. After her grandmother died, she’d hated SRP. She’d hated them until they championed the snake. Then she’d loved them. The snake was supposed to make power available for everyone, rich or not, as long as they wanted it. Since the rich had their own systems, the snake was a public work for the poor. The cheap power and net connectivity that ran down the snake had helped her compete in high school, helped her get grants for college, helped her with

everything for five years. Now all that was threatened, and for no reason Rosa understood.

"You should go," Inez said.

Rosa nodded, glancing once more at the destroyed sections of the solar array. "I'm tired. I've been working all day."

"Killed a boy when that came down. Nine months old."

Rosa swallowed. "I'm sorry." That hadn't been in the regular news. But she'd be able to find the information if she looked. This neighborhood had its own news sources that flowed through the knots of idle poor like water running downhill.

"Come back on a better day," Inez's smile was faint, but genuine. "I want to know how you are."

Rosa thought about leaning in for a hug, but extended her hand instead. Inez took it, her grip strong. She repeated her request. "Come back."

"Soon." It felt like an empty promise and she wondered at that, unhappy with herself. What right did she have to ignore this place she'd come from?

The next morning, she arrived an hour early for her shift. As she threw her lunch into the crowded fridge, she said, "HANNA. Good morning. Anything?"

As always, HANNA was right there. "I found three large contributing factors. We have been working on the tracking system failures."

They had. For a year. "And there are still no parts. Go on."

"Weather."

Rosa sat down and began turning up her systems. "Like the dust

storm from hell."

"And the one before that? No. It's an average of three degrees warmer so far this summer."

"I know that," Rosa replied.

"People have used seven percent more air conditioning."

She hadn't known that. The SRP staff infoweb loaded up on her screen.

"And power is leaving the system."

"I know." She scanned the web. The brownout schedule would post in 15 minutes. Call-takers had been pulled in early. The Emergency Operations Center would stay activated. A hot wind would come today. No storm. She blinked. "How much power? More than usual?"

"The usual amount. Twenty percent."

She frowned. HANNA was feeding her data slowly, making her think. One of its described duties was staff training, but she'd thought she was beyond most of that. "So it's 20 percent of power, no matter how much we generate?"

HANNA said, "It's a fixed amount equal to 20 percent of full capacity."

Rosa stopped moving. "That amount doesn't get reduced in an emergency?"

"No."

Her screen filled with snippets of contracts. She had interned with the law department; she could parse the language. As she reviewed the clauses HANNA sent, a deep revulsion rose in her.

The governor had signed away 20 percent of their power.

The SRP power grid was the snake, and it was meant for Arizona's poor and middle classes. Not for the cooler north. She poured a cup

of coffee, took a deep breath, and went to find her boss.

Susannah Smith was in her office, drumming her fine, thin fingers on the table. Her usually curled hair hung around her shoulders, still damp, and she looked as tired as Rosa felt. Nevertheless, she glanced up and smiled as Rosa entered. "Did you sleep last night?"

"Not well."

"Is everything OK?" Susannah turned her attention back to her computer. "The lists just posted. I hope you brought a lunch. We may not get out today."

"I have a question."

"Ask away."

"The governor sold our power. Did you know that?"

Susannah turned back around. "We've always sold off our excess power."

"This isn't excess. Chicago and Salt Lake have first dibs. That's new."

For a brief moment, surprise flashed across Susannah's face, and her lips opened to speak, but she clamped them into a frown. She shrugged. "This is not our problem. We support maintenance, not contracts."

"But surely in an emergency ..."

Susannah's glare was uncompromising. "We can't fix it."

Why did Susannah look so angry? "Why not?"

"Not you and I. And not today." Susannah stood up, which made her a few inches taller than Rosa. "Can I help you prioritize your work?"

Rosa wasn't ready to give up. "Who can change it?"

"The ASP." Susannah took a step toward her, not menacing, but pressing. "Go on. We've all got full plates today, and long days."

True enough. "I can't—"

"Go."

Susannah had never used that tone of voice with her. Rosa went, angry tears stinging the corners of her eyes and nails digging into her palm.

Back in her office, HANNA swept her into work and she spent the morning cataloguing the missing solar panels, checking HANNA's designs, and approving orders for materials and for the maintenance bots. At least they didn't need to worry about the price of replacement panels. The governor had managed to get an emergency declaration and FEMA would pay.

Every way she could think of to fix this was constrained by the governor's bad contract, or slowed to idiocy by the multitudes of safety mechanisms that threaded throughout SRP—half of them relics from the days when power ran on high-voltage lines and touching it killed.

Right before lunch, Rosa sent a note to Callie, who had been her formal mentor when she started this job, and who had continued to help her. Callie could get anything through the stifling bureaucracy. She agreed to meet in Rosa's office for lunch.

Callie plunked her huge frame in the chair and threw her head back, almost dislodging the big, messy bun of gray hair that crowned her head. "Are you as tired as I am? The phones are crazed, and there's three old women with protest signs out front. Hard to spin this."

Rosa told Callie what she'd learned, and shared her conversation with Susannah.

Callie frowned. "That's way upstream. There's nothing we can do."

The word *we* gave Rosa hope. "Are you sure?" She glanced at her computer. "It's 118 degrees already." Her voice rose. "People will die,

to give power to Chicago, where's it's only 92 degrees. There's nothing fair about that!"

Callie shook her head and popped open a coffee bulb. "No. But you and I can't change it. Policy. I can get stuff done, but only to support SRP or the workers." She sipped her coffee, brows furrowed. "You mess with this, you might get fired."

"I told Susannah. She was surprised. I could see that in her eyes. But she sent me away."

"Susannah's been here long enough to know what's what. Some things." Callie rolled her eyes and held out a coffee bulb. "Have one of these."

So Callie wasn't going to help her either? Rosa took the coffee, and drank so fast she burned her tongue.

During her next break, she used her personal phone to try calling the governor. The lines were busy.

Every little thing she did to help fix the snake felt like pulling a single needle out of a ball of cactus. This shouldn't be an emergency, and they shouldn't be using workarounds and running bots past their maintenance cycles. They should have time to be careful.

She ran into Callie on the way out of the door. "This is still wrong," she told her. "Three people died already. Old people. In one day of brownouts. It will get worse."

"The city is opening cooling shelters."

"For how many people?"

The look on Callie's face told her it wasn't enough, and she didn't even answer the question. She just said, "You're doing your best."

"It's not good enough."

"All you can do is your best."

Rosa stared into Callie's eyes. "Maybe I can do better."

It was already bedtime when she finished wading through the

heat to her one-room apartment. Someone had posted the brown-out schedule on her door, and a list of power conservation tips. She glanced at it, realized she had two more hours of cooling, and passed out on the bed in her uniform.

When she woke near dawn, her limbs were heavy with a dark anger she couldn't put any images to. Sweat beaded her brow and clung to her hair. As she stared out the window at the whitening sky, the anger pushed her out of bed and into a clean uniform. She ate a handful of berries and two pieces of toast, then plaited her hair into long braids that would be cool.

She stepped outside and started toward work, then she stopped. If she went in this morning, the anger would consume her. She had felt pride in her work until yesterday. Not now. She worked for the power company, and she knew what it was to die from lack of power. Her hands shook, so she clenched her fists. She turned and walked fast back toward her old home. She could lose her dream, her job. But if she could save a grandmother somewhere ...

Usually, the long canal soothed her. But this morning, the whole thing—the wide canal, the arching snake of power, the graffiti on one wall, the elegant natural art on the bridges—all of it felt like separation.

Inez was easy to find; her mother and sister still lived in the same old, faded green house. While the sister told Rosa where to find Inez, she kept glancing warily toward the SRP logo on her shirt. But she asked no questions.

Inez sat on the front stoop of a pop-up brick house, small and square and exactly like the three next to it except for a mural of a donkey on the side wall. Inez's children were both slender and

dark-haired and shy. After introductions, Rosa asked, "Who matters here now? Who tells the neighborhood things?"

Inez stood, the boys behind her, the taller one peering out and the shorter one hiding behind Inez's ample right thigh. "What news do you have?"

Rosa told her about the contracts.

Inez looked more angry than surprised. After a few moments, she asked, "Do you remember Penélope López? She was two years behind us in school."

"Maybe." She imagined a thin girl with short dark curls who liked high-heeled boots, even in summer.

"She's got a local show. Regular dissenter, that one. A good girl." Inez picked both boys up, balancing one on each hip. She pounded on her neighbor's door and shoved the boys inside, then led Rosa to Penélope, who still wore high-heeled boots, but was taller now, and angry. Rosa told her story and Penélope wrote.

As she talked, Rosa's stomach burned. She was an hour late to work, and she was wearing an SRP uniform and telling tales on the most powerful public company in Phoenix.

Next, Inez took her to Jack, a tall black man in dreads with a soft smile. He had read Penélope's post. "I love what you said. Truth to Power." His smile widened. "May I? It will be live. It will be now."

Rosa swallowed. "Who will see it?"

"Everybody."

Rose hesitated.

Inez watched her.

Jack smiled, full of patience.

Rosa nodded.

Jack handed Inez a camera so small Rosa kept losing sight of it. She was careful only to say what she knew, to use facts, and Jack

asked her hard questions. When she refused to answer some, he said, "That's okay. You can refuse. That tells us as much as an answer."

That made her stop and breathe, and worry, but she kept going. She was saving a grandmother.

Jack held out a hand, leaned in, and hugged her, smelling faintly of smoke and apples. "You're brave," he whispered. He led her to the canal, and they stood near the break where the hanging wires showed. He asked her some of the same questions again while Inez zoomed in on her shirt and her brown face and long braids.

Rosa leaned into her words. It was hers now, her choice, her story, her anger.

An old woman who carried herself like a turtle came up and hugged her. She turned to Jack, who interviewed the old woman while she called for everyone to come and protest, to stand under the shade of the snake and be heard.

Penélope called Inez, and said she, too, would call for a protest.

Over the next hour, the paths under the snake began to fill. People brought water and food, chairs and signs. They also brought anger, children, dogs, and music.

Rosa did three more interviews.

By the time the Phoenix news channels showed up, the paths were full, and rumors that other neighborhoods had joined reached her. Even middle-class neighborhoods, ones that had their own power. A news program let her read their signs, which had been crafted with glue and glitter and fancier markers than the ones near Rosa. But they said the same things.

POWER TO PHOENIX
THE SNAKE IS OURS
POWER FOR ALL

As the day wore on, the signs grew angrier and more clever.

THE SNAKE FEEDS US ALL
GET THE SNAKE OUT OF OFFICE
FOR THE SNAKE OF POWER

A college-age couple resting on a bench shaped like a rock with thornless cactus arms recognized Rosa and stood up together, gesturing for her to sit. She blinked at them for a moment, but when the woman inclined her head and quietly said, "Thank you," Inez sat and pulled Rosa down next to her and the couple melted into the crowd.

Despite the snake's shade over the bench and the water flowing five feet from them, the heat punished. Protestors clumped together under the solar panels, and Rosa swiped sweat from her brow. Young men worked the crowd, selling metered pours of water from great sacs they rolled in front of them on red wagons. Newscams hovered in the air, some clearly violating the rules about proximity to people.

Felipe, who Rosa had burned for in eighth grade, came and shook her hand. His warm, sweaty touch drew a nervous smile and Rosa momentarily felt like her younger self even though Felipe dangled a girl of three or four on his hip.

An international news channel came by and interviewed her in horrible Spanish, and she managed not to laugh while she repeated her simple litany of facts. The reporter's camera zoomed in on the logo on her shirt. "You are a whistleblower?" he asked.

She shook her head. "I love my job, and SRP. But people had to know about the contracts. Three people died from heat already today. More will."

Voices rose. A water seller who had stopped near them after selling out climbed up on his wagon and called out, "Police!" He turned

and faced Rosa. "They come for you! Go."

Rosa stood, confused. People bunched in front of her, some chanting *Save the Snake*! or *Power to the People*!

Inez climbed up on the back of the bench. Her eyes widened. "Riot gear."

In spite of the wilting heat, of a hot wind, of the sun now high overhead and unrelenting, in spite of all that, the crowd continued to bunch. Inez said, "They're blocking the police."

The water seller, peering back and forth like a crow from his vantage a foot or two higher than her, said, "Not for long."

A hand fell hard on Rosa's shoulder. "There you are."

Rosa turned to find Callie staring at her. She'd stripped off her uniform and wore a hat that might hide her face in such a large crowd. "Susannah locked you out of the building."

It didn't surprise Rosa, but it hurt.

Callie offered an unexpected smile and said, "I told this to the *Arizona Republic*." She looked like she had just won the lottery, her eyes glittering with energy.

Rosa stuttered. "You ... you did? Couldn't you get fired, too?"

"No. I retired before I talked to the paper. I came because of you. What you said to me, that we had to care, you made me ashamed."

"So you're safe?"

"Yes. I think so. But you're not."

"I don't mind." Rosa leaned in to hug Callie. "Thank you."

"I came to thank you. For saying you could do better. I decided I could, too."

Rosa smiled.

The water seller called, "Something's happening!"

Rosa glanced at him, but Callie said, "Wait."

When Rosa turned back, Callie told her, "HANNA and I did

something before I lost access."

Inez, still balancing on the back of the bench, called out, "They're coming closer. We can move faster than they can. We should go."

Callie shook her head. "No need. HANNA helped me turn off the transmission."

Rosa blinked. "What transmission?

"The lines going to Chicago. I know someone with a backdoor to HANNA, and he helped me. It's enough. Just the protests might have done it. But you made me want to help. The governor will announce soon."

Rosa stared at her mentor, blinking back tears and sweat. Callie had always loved her job, always defended it. She had hated much of the process, but never the real work. And now she had been this insubordinate? "Will they arrest you?"

Callie was still grinning. "And admit their own AI helped?" She shook her head. "There will be a press conference. The governor will say she was going to use the money to repair the snake."

"Was she?" Rosa asked.

Callie shrugged. "Who cares? We win. People don't die."

The water seller said, "You should go."

Rosa looked at Callie. "Other money can pay for repairs."

Callie glanced at her watch. "It might already be over."

A roar from the crowd was hard to interpret, a wave of tired whoops and louder calls, a few whistles. The water seller said it first. "The brownouts are cancelled."

Rosa and Callie shared a long smile. In spite of the heat, Callie folded Rosa in her arms. She whispered, "I'll find you."

Rosa turned to help Inez down. By the time she looked for Callie again, she was gone.

"You did this," Inez said.

"I had help."

"This wouldn't have happened without you."

The water seller hopped off of his wagon. "The police are almost here." He began to move away, and Inez pulled Rosa after him, and in a moment the crowds had enfolded them both, pushing them down the river of people under the snake.

She had done better. She would find a way to bear the price. It felt good to be home.

Lessons from the Snake: Energy and Society

By Joshua Loughman

As a scholar who focuses on the intersection of technology and society, I'm struck by the seamless interweaving of the two in Brenda Cooper's story "For the Snake of Power." The story captures both a compelling struggle between characters and the complex unintended consequences stemming from emerging technology.

A major framework for thinking about the future of energy and society is the *energy trilemma*. This framework considers three important dimensions that are in tension: energy security, energy equity, and environmental integrity.

Ensuring energy security in electricity and fuels is costly, as it entails maintaining redundant systems to cover an array of possibilities and requires resiliency in the face of threats ranging from natural disasters, terrorism, and aging systems to fluctuations in commodity prices and international trade. Investments are made decades in advance, which means that decisions are made with significant uncertainty. Striving for security means the most demanding cases have to be planned for. Trying to optimize for energy affordability and access can reduce the capital needed for

investments in new technology and maintenance of multiple infrastructures. But cheap and abundant energy, produced primarily by fossil fuels, leads to greater emissions, making performance in the third leg—environmental integrity—difficult.

The story navigates these tensions overtly in some places and subtly in others. Energy security is in part a result of having resilient systems. As the snake succumbs, in part, to natural disaster, we witness the logic of energy security and the need for redundant, overlapping systems, which are lacking in this case. The story's focus on an unfolding crisis also highlights the technical points of failure (the damage due to the storm) and the social and political points of failure (the failure of energy security due to social arrangements—in this case, a public-private energy contract). The story is timely, as there are clear parallels with the ongoing challenges faced by Puerto Rico concerning the failure of their energy system in the long aftermath of Hurricane Maria. Energy equity turns on the issue of access. The central conflict in the story is the lack of access, for the local community, due to the esoteric contractual commitments between the Salt River Project utility and other cities outside of Arizona. Lack of access due to brownouts is not all, though. As prices rise, the cost of access is equally important. Some in the community can afford to be off-grid with their own solar systems, while large segments of the community are left in the dark in the event of a crisis. As for environmental integrity, the third leg of the energy trilemma, the story addresses this more subtly. There are a few reminders that the future will be hotter, although it's already scorching in Phoenix during most of the year. Even with substantial changes in energy systems to reduce emissions, significant warming is locked in. The global phenomenon of climate change will have local effects on land use and water use, as

well as changes in ecosystems.

Beyond the energy trilemma, "For the Snake of Power" highlights a more fundamental concern about energy configurations. By depicting a large-scale plant that resides in an urban environment (as opposed to, say, a highly distributed solar scheme with panels on rooftops, in yards, etc.), the story makes it clear that there are many alternatives when thinking about energy futures, even when we limit the technology to a single kind of energy collection process like solar. When thinking about the rapid growth of renewables it's easy to fall into the habit of thinking that our choices are between fossil fuels on one hand and clean-energy alternatives on the other. But even within the category of solar energy, it's clear from this story that we need to question that binary assumption and appreciate the different ways these systems can be configured.

Among energy scholars, there is also debate about the degree to which technologies should be centralized or decentralized. For decades, solar has been hailed as a tool for democratizing energy production and consumption by being distributed and easily configured as a personal energy production tool, akin to a household appliance (think a small cluster of solar panels on every rooftop). In the context of this debate, "For the Snake of Power" is provocative in two ways. First, the wealthy are the first to take advantage of advances in personal solar technology, which exacerbates inequality issues. This is a trend that we're already seeing today: Some studies have shown that, given the way residential solar systems are financed, only wealthier households are able to install them.[1] This puts pressure on utilities to raise prices on middle-class and working-class customers. In reaction to this escalating inequality, the Arizona state government and the public utility, Salt River Project, create the snake. The snake is a community good—public

artwork, community space, symbol of cooperation and equity, and critical infrastructure for equalizing access to electricity. Protests begin when the snake's status as an asset for the whole community is compromised by the governor's out-of-state contracts. Second, the key element of solar's democratizing power is usually understood as its ability to be distributed, allowing for greater individual and local control over energy generation. This story offers an alternative narrative, suggesting that even when solar power is concentrated it can be used to widespread benefit if the political will is there—although that beneficence may need to be defended from time to time.

"For the Snake of Power" has special significance for me because I study how different ways of configuring renewable energy affect social and political systems. Energy systems are critical parts of how we live in the world and are interconnected with the broader sweep of technology, infrastructure, and markets, as well as cultures, lifestyles, politics, and the environment. Despite these inextricable connections, most decision-making about energy systems only takes into account narrow technological and economic factors. The tools that policymakers and energy companies use to inform these considerations are usually quantitative models of one kind or another. These models could be cost-benefit analyses, extrapolation of current trends, or statistical interpretations of economic data—each with their own strengths and limitations. In my research, I explore how a holistic appreciation of social and environmental factors can be integrated into decision tools and the policies that are made with those tools. One of the main ways I do this is by drawing on narratives such as speculative fiction and *scenario analysis*—a method used to systematically explore uncertain futures through dynamic combination of change factors. I look for patterns and dynamics within these stories that aren't well-represented in quantitative models. In "For the Snake of Power," two gems

have inspired some new thinking along these lines.

The first is how the story provides a concrete example of the ways that legal and contractual elements can have perverse unintended consequences. How can we infuse the uncertain effects of policy, law, bureaucratic action, organizational structure, and other similar variables into a quantitative analysis? At a minimum, recognizing that these features are embedded in energy systems will help remind us to question the assumptions of traditional methods built on statistical models.

Second, many analyses of energy systems look at energy production in terms of technical use data, kilowatt-hours, and the like. These measures express the amount of electricity consumed by an end-user, which is often a smooth continuum of data. But in reality, electricity use goes up and down; sometimes communities have an abundance, and other times they have shortfalls. These changes in demand, in traditional energy models, modulate electricity prices in smooth and predictable ways. However, at the intersection of changes in system performance (perhaps due to environmental damage) and extreme weather (heat, in the case of the story's future vision of Phoenix), there are nonlinear results that are extreme and consequential. In "For the Snake of Power," those nonlinear elements are deaths and civil disobedience. As a city or community follows a certain lifestyle and energy use pattern for a long period of time, a path dependency can occur. In Phoenix, most buildings have air conditioning, and this shapes people's behavior. For much of the year, people avoid outdoor activities and opt to stay at home, or shuttle from air-conditioned cars to the mall or the movie theater. Families budget for significant spikes in cooling costs as the weather turns hot, and people of means flee the Phoenix area in large numbers for cooler climes. The hottest summer months in Phoenix can

be as insular as cold winters in other regions—in both cases, people adjust their behaviors and lifestyles to avoid being outdoors. When the AC goes out, that can be a major adjustment and disruption. Some social norms and patterns will lead to improved adaptability and others could result in great vulnerability. For example, as we experience more frequent and intense heat waves, cities that have adapted to living with heat, such as Phoenix, might be able to cope more readily. On the other hand, as communities rely more on the energy infrastructures that provide these services, the more vulnerable they are to system failure. Exploring this idea further will be a great challenge for understanding the intersection of speculative fiction and quantitative energy futures.

Quietly, "For the Snake of Power" is a story about decision-making: which factors and people we choose to emphasize, and which ones are excluded or unnoticed. HANNA, the helpful AI agent and co-protagonist, is a reminder of how decision technologies can be interactive and encourage empathy and critical thinking. The sources of information that decision-makers often rely on, like statistical models and computational tools, can often seem abstract, slavish to objective measures, inhuman. HANNA reminds us that while information is critical for working through the tough problems that crop up with complex systems like energy, we must look beyond markets and technical performance and consider the cultures, conflicts, politics, and messy daily lives of the people who depend on those systems.

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1. See, for example, Clark A. Miller, Jennifer Richter, and Jason O'Leary, "Socio-Energy Systems Design: A policy Framework for Energy Transitions," *Energy Research & Social Science* 6 (2015): 29-40.

Drawing from Nature: Designing a Solar Snake

By Esmerelda Parker

The design features that guided our group's work on "For the Snake of Power" were large-scale urban solar installations with a particular focus on aesthetics. We set our story in a more populous future version of Phoenix—a city which had undertaken an aggressive solar infrastructure project in an effort to reduce energy inequality. This left our group with the challenge of figuring out where we could incorporate a large, continuous installation of solar panels in a densely populated urban environment. Looking at maps of the city, it occurred to us that the canal system twists and turns its way throughout the present-day greater Phoenix area. Projecting that these canals would continue to exist in our future society, we decided that our solar system would run everywhere above them. The placement of the structure would serve two additional purposes: providing shade on the paths running alongside the canal and reducing the amount of canal water lost to evaporation.

The winding nature of these canals reminded us of the curves of a snake as it slithers across the ground. This became the basis for our focus on aesthetics. The snake, as we named our installation,

stretches for miles, looming above the canals as it winds its way through the city. Its panels look like scales, glistening and swaying slightly with the breeze. It is made up of hundreds of miles of small, individual, scale-shaped panels linked together by a series of wires. The design allows enough light to filter through the otherwise overwhelming structure to give a sense of openness to the area underneath, but it does little to distract from its enormity. The vision here was to create a beautiful power generation and delivery system, in contrast to the cruder design of wires strung between utility poles. The wires running through the snake and into the buildings powered by it are concealed in its supportive structures and underground. All that is visible are the snake's scales and supportive structures, integrated seamlessly and artistically.

Throughout the story, we played on imagery associated with snakes. In certain areas of the city, the snake is surrounded by scenes of carnage. The haboob that devastates the snake before the start of our narrative had left panels strewn all over the ground and in people's backyards. Instead of looking like a snake which had shed its scales, the bare skeleton protrudes from the ground like a decaying corpse in areas damaged by the storm. Although only a few days pass without repairs beginning, hopelessness washes over Phoenix's residents because of the dangerously hot weather. This quickly turns to anger at their public utility, Salt River Project. The snake which had once brought cheap power to their homes now seems to strangle their neighborhoods.

This juxtaposition highlights our story's focus on energy inequality. The morning after Rosa confronts her boss Susannah, she finds herself thinking that "the wide canal, the arching snake of power, the graffiti on one wall, the elegant natural art on the bridges, all of it felt like separation." The scale of the snake makes it nearly

impossible to miss, but the damage done by the storm exposes the hidden parts of the snake: wires hanging in tattered messes from the normally seamless array. It's only when the structure has been damaged that the inner workings of the system are exposed—just as the crisis caused by the haboob reveals the legal and political machinery that is siphoning power away from the Phoenicians who depend on it. This narrative runs parallel to Rosa working to expose the other secret part of the snake: where its power is going. This second narrative thread is where we chose to incorporate concepts of governance and ownership. Who should decide where the power from the snake goes and who gets to use it? Driven by her past experiences and dismay at the loss of life from the haboob and the subsequent brownouts, Rosa puts her career in jeopardy to ensure that this power is kept for use by the most vulnerable people in Phoenix.

To tie all of the design considerations together, we wanted to emphasize the fact that the snake is designed to do more than just produce energy. The snake is the largest public works project undertaken in the lifetime of Phoenix's residents. It was constructed to create areas of shade along the banks of the canal, allowing recreational activities to flourish in the otherwise scorching desert. This is especially important in areas of Phoenix that had too often been overlooked for improvements by the city's government. These areas are the ones Rosa is fighting for. She can't stand to see their inhabitants left to suffer in heat that proves fatal for some and overwhelming for many more. To Rosa, the snake and its power belong to these people—not Phoenix, and not SRP. This is why she and her fellow protestors use the snake to gather support, calling on people "to stand under the shade of the snake and be heard" to oppose the selling of power outside of the state. In this moment, the snake reclaims its original purpose: protecting those who need it most.

Small Urban

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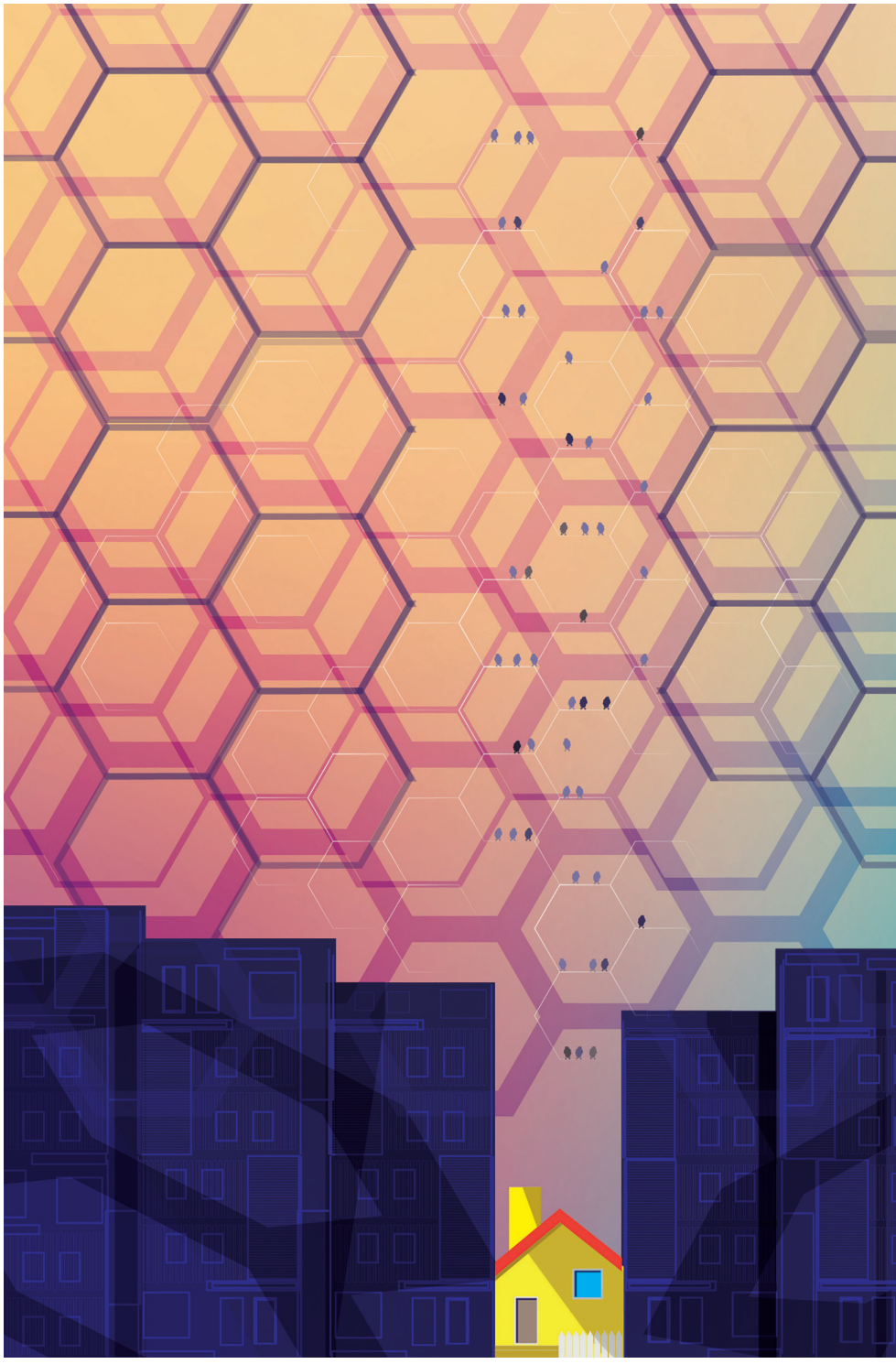

Under the Grid

By Andrew Dana Hudson

"I have a theory that we could measure cultural sophistication by the occurrence rate of puns," Trevor texted. "The more concepts and connections in a time-place, the more linguistic opportunities for people to make bad jokes."

"Uh huh." Ingrid only half watched the noties, focusing instead on swiping through paperwork: HOA waiver tickets to resolve, memos about algorithmic tweaks in the approval pipeline, timesheets to justify her existence to the Emergency Government and their Chinese/European backers. "Guess that 'PhoTown' branding really is an indicator of successful urban renewal then."

"Mayhap one day we'll be so complex that every possible combination of words will constitute a pun," Trevor continued. "This is my singularity."

Ingrid snorted. "Preach!" she tapped.

Three dates in was usually the sweet spot for banter. Seeing each other naked lowered the conversational stakes. Suddenly people let you in on what was actually going on in their heads. But it was Tuesday, and she had two afternoon site visits in Grosse Pointe to prep for.

She had to spend a disproportionate amount of her time inspecting such neighborhoods. First, because rich enclaves resented

Emergency's suspension of municipal governance, so they were more likely to use homeowner association agreements to claw back some of their autonomy. Second, because white people had to be handled with kid gloves if she wanted to avoid hours of "let me talk to your manager" appeals.

Trevor's texts kept coming. "All of which is just a setup for the following: has anyone ever told you ..."

"Don't say it!"

"... It's pretty ironic that you work on the Grid instead of, pause for effect, *in* the Grid?"

"Never, actually," Ingrid replied. "The rapture must be at hand."

"baby ... broke my leg 🤕"

That wasn't Trevor. She picked up her phone.

"Mama, where are you?"

Her mother texted, "🚑🏠"

Ingrid chewed her lip. She looked out her office window, counted the Grid squares below, west to where her childhood home would be, if she could see through the thicket of vertical farms and the patchwork of silvery-black squares. The solar rolled in fractal waves, arranged to maximize sun collection while letting through light and wind—a delicate balance of homeowner investment and computational decree that Ingrid helped manage. And above it all, the Grid: a carbon-fiber scaffolding, white-gray, preposterously massive, cutting Detroit into uneven squares and trapezoids.

Every day she touched the Grid—who didn't?—but she'd successfully avoided that house under it for years. She spent holidays with boyfriends and coworkers, saw her mother only remotely or at church.

She typed three letters, sent: "On my way!"

Ingrid took the monorail out to Springwells—end of the line. This train was a recent addition to the Grid, so it only went a bit outside the tall city core. Extending it further would require negotiating with countless HOAs and individual homeowners to clear a path through their skyspace. It was a mess she wasn't looking forward to seeing farmed out to her department.

She jogged down spiral stairs to street level. From down there, Detroit was a jungle of contradictions. Skinny, single-lot towers stood beside century-old two-storys. The skyspace of these houses crowded with leafy trellises and tubes of aeroponic crops, dangling from the crisscross Grid 100 meters above. The Grid was supported by redwood-thick struts pushing out of the street. These always seemed a bit alien to Ingrid, with uncanny curves drawn by powerful math instead of human hands. They were colossal, yet made mundane by the rows of concert posters that covered the first few meters and the riot of graffiti that snaked up the rest. Bikes wheeled in the roundabouts the Grid had created in this once car-dominated city.

Her mother Krystal's house was little more than a cottage, tucked between two 10-high modular stacks of container apartments. Ingrid paused on the lawn, looked up, sighed. Her mother's skyspace was filled not with an orderly vertical garden or racks of slanted solar panels, but with clusters of boxes and baskets. Dozens of birds—maybe hundreds—sat on and in these houses, or swooped from feeder to feeder. They were of every size and color, and at least half weren't native to North America: parrots squawked at singing robins. They were loud this morning. The cottage roof was white with droppings.

"Mama, did I see chickens up there? They can't fly!" Ingrid said when she pushed into the house. The floor was covered in piles of computer junk, stacks of books. She edged a narrow path into the kitchen.

"Marsha down the block has chickens," Krystal said. "Why should she get all the eggs?"

Ingrid's mother sat in her creaky, Techni-brand recliner, left leg elevated in a gelatinous cast.

"Mrs. Frick's coop is in her backyard. What happens if one of your chickens falls? They aren't agile creatures."

"They got wings. They can flap down. Then my dronies lift them back up." Krystal shook her control board. Ingrid sighed.

"Mama, what happened? How're you feeling?"

"Had to unclog that watering pipe. Drone couldn't do it, and boys across the street stopped helping me. So, went up myself. Felt something buzz me, and ..." Krystal waved at her leg. "Nurses just left. I've got meds. I'll be fine."

She didn't look fine. Though spry for 70, Krystal was thinner than usual and seemed drained of blood, woozy and jittery from the medication. Her close-buzzed scalp had new splotches.

In recent years, Ingrid had watched her mother become uneven. She wasn't senile, exactly, and with robotic assistance she couldn't be called infirm. But manic compulsions set in. Krystal changed her mind often, or was insanely stubborn, each at unexpected times. The hoarding had gotten worse, and now there were the birds. For years Krystal had lived across from Zug Island, exposed to lead pollution and, eventually, the grating "Windsor Hum." Ingrid had followed the studies about long-term effects of this low-frequency industrial noise: anxiety, irritability, spells of illucid thought.

So Ingrid reluctantly stayed the afternoon, puttering around,

clearing space for the drones that would bring her mother food, helping her hop to the toilet on crutches. She moved a pile of magazines, and a stack of unopened mail fell to the floor.

"Mama, have you read this?" Ingrid held up one of the official-looking letters. "Your block voted to associate, put in new rules. Mama, they used the word 'eviction.'"

"Oh, I know it!" Krystal said. "Busybodies think they can get all those Chinese at the PV lab to move over here if they get everyone to spit-shine their lawns. Well, I got deals with everyone next door, so they can't do nada."

"Mama, that's not how that works," Ingrid said, exasperated. "If their waiver goes through, this new HOA can homogenize skyspace use."

"That's what you're here for, baby! That's your job, right? I told them you'd reject that waiver."

Ingrid was aghast. "Mama, no, that's not up to me. This is serious. If your birds aren't in compliance, they can seize the house."

Krystal just turned back to her screen. Ingrid dialed the link on the letter. She got ahold of the new HOA's general manager, David.

"Look, this has been in the works a while," David said. "I'm sympathetic, but your mother had every chance to come to the meetings, help us build a policy that works for everyone."

"She doesn't like to leave the house. Just—what's she out of compliance on?"

"Ms. Hall's skyspace, as lovely as it is, barely met regional generation standards last year. Five months ago the new requirements cycled in, and my guess would be she's now behind. She's lucky Emergency hasn't audited her block lately."

"That's it? We can get better panels."

"Well, there's the matter of the birds. Some neighbors think

they're a nuisance. They dirty solar panels, rip up crops, disrupt repair and delivery drones."

"The algorithm has dispensations for biodiversity."

"Yes, for native species," David said, filling his voice with exaggerated patience. "Your mother is basically running an avian refugee camp. Birds migrating with the climate shifts, escaped pets. Emergency calls those pests."

"What should we do?" Ingrid said. "You can't evict her. She's lived here for decades!"

"We're just following the rules. Get the skyspace in order, talk to Ms. Hall about the birds. Then we'll see."

Ingrid sighed. She'd have to stay.

Trevor worked in HR, so he smoothed out her leave of absence. He even agreed to feed her cat.

"Thank you!!!!!!" she wrote. "I'll make it up to you ;)"

"Now, now," Trevor texted. "Here at Grid HR we are all about Guiding Responsible Interactions Diligently."

"Are acronym puns your new thing? Can I veto that?"

"Not if you want to keep Getting Really Interesting"

"Diatribes?"

"I was going to say Dates."

"Sure you were."

Ingrid moved onto her mother's couch—just for the week, she hoped. She had to clear off dozens of misprinted birdhouses, and used this as an excuse to purge a good chunk of her mother's hoard. Krystal, pacified by painkillers, didn't make a scene.

Next Ingrid rented a safety harness from an HOA-approved

vendor and ascended the nearby Grid pillar. Halfway up she clipped in and moved along a horizontal support beam to the subscaffolding that made it possible to use the 300 vertical feet of airspace Krystal legally owned above her house. Ingrid's stomach fluttered at the light feel of the carbon fiber under her, but she knew that the Grid was impossibly strong.

From a generation perspective, Krystal's property was a mess. Ingrid didn't need an algorithm to see that the single solar panel on top was poorly aligned, partly shaded by the newer array above the neighboring tower. A few yoga mats of flexible PV dangled vertically, wobbling beneath the birdhouses, catching only a few random rays that trickled through the patchwork sky.

Detroit wasn't Phoenix. They got less sun, and the heat island here was not so profound as to warrant a full-city roof, even under Emergency's generous interpretation of its mission. So, in the spirit of assisted bootstrap-pulling, Detroit had instead gotten a half-infrastructure: a frame, planted by giant Chinese construction bots, into which individuals could plug the means of meeting their landowner watt-and-calorie contribution quotas. Quotas her mother was behind on.

Ingrid inched into the skyspace. It was windy. A pigeon banked by her head, and she flailed. She trusted the harness, but a fall could still wrench her shoulder. Spooked, she crouched on the catwalk.

"Mama, can you keep these things off me?" Ingrid sent. "No wonder you took a spill."

" 😤" Krystal replied, but a pair of quadcopters zipped up to escort her.

A ladder went up one side of the mass of birdhouses. Ingrid clipped and climbed. They were beautiful, in a way, an Escher jumble of painted boxes, half-eaten seed cones, plastic watering flowers, sacks

of thistle only finches could land on. Hummingbirds inspected her furtively. The cooing was loud and rhythmic, vibrating her organs.

At the top, Ingrid examined the underside of the solar panel. There was a simple servo to track the sun, but pigeons had nested in the crook of the hinge. Pigeon waste was like cement when it dried, so the mechanism was frozen by a sticky mess of rust, poop, and feathers.

"Don't you touch that!" Her mother's voice came from the buzzing quadcopter's tinny speaker. "We're waiting on chickies."

There were speckled blue eggs in the nest. Ingrid pulled herself up to get a better look. The quadcopter poked her in the rump.

"Hey!" She swatted at the drone, and her fingers got smacked by the spinning plastic blades. Smarting, she climbed down.

"Ugh this is why I got an office job!" she texted Trevor.

"Isn't this your wheelhouse? Inspecting skyspace for compliance?"

"Not while fighting off storks and my crazy mother's drones!"

"Jared in legal told me about some dude in North End who trained a falcon to swivel his neighbor's panels out of the way," Trevor wrote. "Can you believe that? A falcon!"

Ingrid could believe it. Sun was money. While algorithms did the heavy lifting maximizing where and how to collect solar energy within the Grid, legal precedents ensured there was a lot of play for property owners to customize and, at times, get an edge by undercutting their neighborhood competition. This illicit jockeying was a big reason why HOAs were popping up, but these came with their own compliance concerns. Compliance drift for a single house was hardly a blip, but for 40 houses, it mattered a great deal.

It occurred to Ingrid that even if the neighborhood's waiver didn't roll through her desk—and the automated conflict of interest system ensured it wouldn't—she could still review it. If she found something

off, she could Append Recommendations. She chewed her lip.

The next few days Ingrid alternated between fixing up her mother's skyspace and poring over the new HOA's paperwork. The repairs were tough but satisfying work. Waving at neighbors tending window boxes, she felt a new appreciation for the effort that went into living under the Grid. She lived in a downtown apartment, spent most of her workday in spreadsheets. Site visits were about confirming reported numbers, not getting her hands on the physical machinery that fed the Grid. Now she raised, expanded, and replaced her mother's PV apparatus to catch better sun. Climbing ladders, using heavy tools at awkward angles, balancing on narrow Grid branches—these left her sore in muscles her Pilates app missed.

The paperwork was less satisfying. She couldn't find a digit out of place. David was a well-paid professional who handled multiple HOAs. He had clean templates and had been in business long enough to know which way the algorithmic winds were blowing. The new rules contained nothing that hadn't already been approved elsewhere a dozen times.

Then there was her mother. Krystal spent most of her time in her chair, occasionally hollering for Ingrid to take her to the bathroom. Or to clear away the piles of wrappers that accumulated as she munched down greasy drone delivery from a rotating cast of local home cooks. She watched videos in her panorama helmet and sent spider-like camerabots crawling up the Grid to photograph the birds her skyspace attracted. She printed these out big and glossy, and had Ingrid pin them to the walls around the house.

"Ohhh, look at this pretty fella!" Krystal said, zooming in on one. "So plump!"

"It's very, uh, red," Ingrid offered. Her mother always joked that she'd take up birding "soon as this egg leaves the nest." Surprising everyone, she followed through.

"Scarlet tanager, breeding male. Never seen one with this much orange in the plumage. Isn't he gorgeous?"

It was, Ingrid had to admit. Looking at the high-def stills and elegant gifs, she could see the appeal of getting to see these little nuggets of color and life.

"Mama, why do you gotta bring them here? The Grid's not good for them. There are birding groups for seniors. They'd take you out to the country."

"I don't 'bring them here,' baby. Times have forced them out. We built over their homes or made it too hot. Now we're saying, 'move along, this spot ain't for you.' Where have I heard that before?"

Ingrid thought about this as she made her way back to the core. The nurses were visiting to iterate Krystal's cast, so Ingrid had cleared out to meet Trevor for date number four. Over falafel on the Riverwalk, she recounted the conversation.

"She's right, actually," Trevor said. "Native versus invasive is a totally arbitrary distinction. Kind of a holdover from when the Endangered Species Act was the best tool the environmental lobby had, I think."

"Uh, I'm going to guess that's a gross oversimplification."

"Okay, maybe. But these days we can't assume that any ecosystem will support a particular species indefinitely. So instead we could just try to support as many lifeways as we can." He tossed his last bit of falafel at a nearby squirrel. "Do you always do that when you're making a decision?"

"Do what?"

"Chew your lip."

David the HOA manager didn't live in the neighborhood. Ingrid trucked out to the address on his email signature, in Sherwood Forest. She'd expected an office park, but instead found a big brick house with pretentious round chimneys.

David answered the door holding a baby. For a second, racial anxiety flashed over his face. She saw him suppress the thought that this strange black lady might accost him on his porch. Then David smiled, waved her into his annoyingly tasteful study.

"Had to move my office home when my wife got a fellowship in South Greenland," David explained. "What can I do for Emergency, Miss Hall?"

"There's a new body of Brazilian law that uses bio-difference and bio-density metrics to meet the International Emergency Accord quotas," Ingrid said. "They call them 'multispecies cities.' It's all very hip, very 'next nature,' 'Anthropocene as birth canal' kinda stuff. Springwells Village could pioneer something similar in Detroit."

The baby stirred, and David produced a bottle. "These Brazilians wouldn't have anything to say about bird habitats, would they?"

"Everyone can win here. My mother can stay. The birds can stay. You get to not evict a sweet old lady. We can probably even find some grant money to pilot this."

David did his exaggerated patient sigh. "Miss Hall, I'm successful because I help communities meet the only metrics that really matter: energy and peace. You have enough of those,

you can do pretty much anything else. Like contribute to the Swerve, so my daughter here can grow up without having to be afraid of the sky. So when your mother's birds increase the maintenance burden of the whole block, and get aggressive enough that neighbors are reluctant to climb up and improve their skyspaces … it's hard to feel like everyone's winning."

"I don't see any Grid panels over your house," Ingrid said. She knew it was a crap deflection, but she decided to power through. "If you really thought kicking my mother out was going to move the needle on your daughter's future, you'd be out there hand-cranking a sequestration tree instead of talking to me."

"Okay," David said. He pointedly checked his watch. "Look, you're right. This is small potatoes to me. Have Krystal submit an amendment to the HOA rules. We'll vote on it at the meeting next week. If it doesn't pass, she'll have to either lose the birds or lose the house."

Ingrid fumed. She almost said *spoken like every gentrifier, ever.* Instead she said, "Fine."

Ingrid wasn't an organizer. She'd dabbled in college politics, but that had been dominated by the confused rage people felt when Emergency was declared. You heard about a protest and just showed up, hoping it was about something you agreed with.

Still, she thought she understood the basics: talk to lots of people, explain your side of the debate, ask for their support and their help talking to others. She blitzed through app courses on local-politics best practices as she zigzagged from door to door.

Neighbors who knew Krystal were sympathetic. Many had known

her for decades, had seen her grow infirm and eccentric, and relished the chance to support her in a concrete way.

"It's a good thing you're doing, dear," Marsha Frick said, feeding her chickens. "They're just little birds! This ain't a Hitchcock movie, and we ain't trying to live in some sterile bubble. 'Course we should let her be."

Harder were the younger folks who'd moved into the apartment stacks flanking the cottage. Amid their highly mediated lives, the material and social reality of a crazy bird lady next door was foreign and anxiety-provoking. They hedged, and Ingrid spent more time than she'd planned cajoling them from the fire escape.

"We all give up stuff to live in a community," one white twenty-something said, nervously braiding his beard. "Like taxes and stuff, right?"

"Sure, yes," Ingrid said, trying not to get frustrated. "But are we really a community if we can't care for our most vulnerable neighbors? And that means both Ms. Hall and the birds. Plus, under this new rule, you'll get splash credit for the biodiversity your space accommodates."

All this was draining. She could only have a few conversations per hour, if she was lucky, and the HOA was bigger than she'd thought. On the weekend, Trevor came down and helped her cover more ground.

"These two dudes laid into me about some drones that got downed by a goose," Ingrid texted him as they worked opposite sides of the street. "They're the guys who wouldn't help mama with her watering pipe. They're for sure voting against us. Honestly half-suspect they were the ones who buzzed her on that ladder."

"Ugh, that's awful honey :("

"You're calling me honey now?" In all the urgency, they had totally

breezed through the Meet-My-Mother stage of the relationship. Who could say where they stood now.

"Yeah but pronounced more like hun-nay and spelled HONAE."

"Fine, I'll bite. What's that stand for?"

"Helping Organize Neighbors Against Evictions!!!" Trevor said, in text that sparkled ridiculously. "It's the name of our new pollinator-themed housing justice org!"

Ingrid laughed, but then sobered. She actually had reached out to local tenants-rights groups, but her strategy was too odd, the case too murky without an evil landlord to defy. She'd shrugged it off, but now she was appreciating just how much help help would be. There was just no time—which David had made sure of.

Krystal texted her then: "we winning the 🗳️ baby"

Ingrid couldn't tell if it was a statement or question. Question, probably. She bit her cheek, texted back: "Yes!!"

" 🙏🏾✊🏾🙌🏾 "

There wasn't much else to say.

The HOA met in the old Patton rec center, right at the edge of the Grid. The multipurpose rooms smelled like yoga sweat, the hallways like chlorine. They arrived early to glad-hand, Trevor pushing Krystal in her wheelchair. It was crowded.

"Who are all these people?" Ingrid hissed. She'd canvassed nonstop, but still only recognized half the attendees. Must be all the folks who didn't answer their doors.

Modern HOAs weren't the developer-captured half-democracies they had evolved from. Rather, within the strict algorithmic confines laid down by Emergency, HOAs emulated the role of the abolished

municipalities they had sprung up to replace—often with a kernel of radical democratic culture fizzling in their heart.

Springwells meetings ran on Robert & Regina's Rules of Order, where a Progressive Stack system that forwarded marginal voices governed open discussions, which set the stage for formal debate. This allowed new people and ideas to join the conversation, without derailing the work that those in the know had done staking out coherent positions. Ingrid had done her best to "stack the stack" with "well-leading" questions from supporters, which sounded innocent but had answers that boosted their reasoning. But she still had the tricky task of arguing for the Brazilian Amendment in a way that won over people invested in the policy question, without confusing the people that just wanted Krystal to keep her house.

The meeting dragged. More strangers shuffled in, regulars who knew the pace of the agenda. After the first hour, she started getting apologetic looks from supporters as they slipped out, late to pick up kids or hit their shifts on the East Asian cam markets.

Still, when the amendment came up and Ingrid gave her speech, she felt like she really moved the room. People clapped. There was a solid amount of nodding. Everyone seemed to feel a deep empathy for the odd old woman whose daughter had come to plead her case.

"Okay, someone want to call the question?" David said. Marsha Frick did so, and hands went up to vote. Eyeballing things, it did seem close.

Later, after she'd finally gotten Krystal to sleep and gone through the motions setting drones to fill the bird feeders overnight, Ingrid walked with Trevor under the claustrophobic sky.

"Where did we go wrong?" she asked.

Trevor shrugged, somehow made it look compassionate. "Politics is hard. Some people voted online without knowing what the amendment was really about. Maybe we didn't have enough time to reach them, or maybe this was just always a long shot we weren't going to win."

They passed a strut, and Ingrid ran her hands over its weird, plasticky bulk. Above, solar panels were uncanny squares of darkness, blotting out the stars.

"Where are they going to go?" she said.

"Who?"

"The birds."

"I don't know. North, probably. Canada is doing a lot of rewilding. They'll land somewhere."

Move-out day sucked. Krystal alternated between terrorizing the movers with her drones and bouts of depressive sobbing. She wailed at seeing her horde purged, her bird habitat dismantled. All this made Ingrid a mess too. Her hands shook and she chewed her lip bloody. She kept excusing herself to the bathroom to run a four-minute-meditation app, which didn't work.

Their car followed the moving van half an hour out to Southfield, miles past the edge of the Grid. The neighborhood was old ranch-style houses, set back from the street, once-grassy yards given over to bulk solar, rolled out flat on the lawn. The elder compound was a set of three modular apartment stacks, buzzing with delivery drones. When they pulled up, management was lowering Krystal's new rooms into place atop the stack—a Tetris L block descending

by crane.

The facility had an elevator and nursing staff on site, physical therapy accessible by bus. Apartments had window box gardens; a farmers market brought fresh produce on Tuesdays. There was good bandwidth for Krystal's games and shows.

Ingrid wheeled her mother around the block to the little nature preserve the forums said was an up-and-coming birder spot. A well-kept boardwalk wove through the trees, to a bench looking out on the muddy lake. The water was gray, and so was the sky. Krystal sat in her chair sullenly.

They waited there a while, Ingrid trying to decide what to say. She'd avoided Krystal for years, but she never thought she'd be the kind of daughter to ship her mother to an old folks' home. She put her head in her hands.

When she looked up, Krystal's eyes were sharp, trained on the lake.

"Look there," Krystal said. "Three egrets. Never seen more than one at a time before."

The white birds had landed in the shallows. They stretched their long necks, dipped beaks into the water.

Ingrid and Krystal spent an hour there, watching warblers and chickadees land and take off again. Like planes at the airport, Ingrid thought.

Her first day back at work, Ingrid tapped listlessly through her inbox. Waivers, algorithm tweaks, HR memos. Considerate Trevor had asked what frequency of texting she preferred while she caught up.

"I can do anywhere from torrent to drought," he'd joked as she left

his place that morning. “But be warned, you’re damming a mighty river here. The chats must flow!”

She’d asked for radio silence to focus, but now she caught herself staring out the window at the sprawling Grid. For once she wasn’t looking at the placement of panels or the hanging gardens, but at the little specks flitting in between.

She texted Trevor, asked where HR put job postings. She found the database, keyed in “multispecies.” Half a dozen openings at multispecies pilot projects popped up. It’d be a pay cut, but Ingrid didn’t mind. She closed her other tasks and started on the paperwork.

All Politics is Glocal

By Lauren Withycombe Keeler

I'm a bit of a reluctant futurist. I frequently encounter depictions of the future, from pop culture to strategic planning, that hinge on innovations in science and technology which revolutionize the human experience. But I just don't think that's how it works. "Under the Grid" is different. It's a future that's achievable with very little modification to 2018 technologies. It really isn't scientific innovation that gets us to Detroit Solar City, aka Pho-Town, in the 2040s; rather, it's changes in governance—in the way people and institutions come together at very different scales and change the physical world around them. That's the kind of future I want to talk about. But innovations in governance are hard to bring about—as the literary critic and theorist Frederic Jameson once observed, it's easier to envision the end of the world than an end to capitalism.[1] "Under the Grid" is a story about the triumph of complexity and the illusion of control and how two scales of governance, local and global, converge to transform how energy is produced, electrifying a struggling city in a struggling country. Make no mistake, the changes in governance that appear in this story are significant and plausible. I find them fascinating.

The story subtly toggles between global and local governance. Chinese and European "backers" financially and literally prop up

the Grid, alluding to a shift in the international order that creates a backdrop for the narrative. As of June 2018, the Chinese government held $1.18 trillion in U.S. debt[2], making it the nation's largest banker. So, the proposition that a not-too-distant future has China wielding this leverage to influence domestic infrastructure development and energy production seems quite plausible to me. It's also fairly consistent with how states and international organizations have conducted themselves in the postcolonial era. Today, it is considered copacetic, if not laudable, for "developed" countries to provide aid to "developing" countries, so that they can, in turn, hire developed-country contractors to build dams, roads, and utilities, thereby pumping the money back into their own economies. In "Under the Grid," the United States becomes the focus of such international development work, a new frontier for the global-development-industrial complex. The U.S. is sick; addicted to fossil fuels, automobiles, and single-family homes. Many of our international brethren were addicted too, but they're kicking the habit, getting clean (energy). But we're dug in, letting our infrastructure crumble, an underclass develop. Any halting, let alone reversal, of climate change impacts will require transformation in the United States's energy and transportation systems, but we're not budging. International foundations and other funding bodies are already turning their sights on the U.S., pumping money into research that can crack the American carbon quagmire. In "Under the Grid," the global family has staged an intervention, and we see the United States in recovery under the watchful eye of Emergency, trying to reassemble American life and American infrastructure for a new age.

What is this "Emergency?" How is it that a fiercely democratic society lets itself be run by an unelected body, let alone a maligned federal agency? Here's how: Imagine for a moment that the extreme

weather of the 2010s continues into the 2020s without proper investment in infrastructure (U.S. infrastructure received a D+[3] grade from the American Society of Civil Engineers in 2017) and response capacity. The U.S. Federal Emergency Management Agency (FEMA) is required again and again to respond to hurricanes, floods, and tornadoes of increasing intensity. Meanwhile, income inequality continues to balloon. Those who can afford it insulate themselves from the worst effects of climate change, while a growing underclass contends with disaster after disaster. Consider this: in 2017, the U.S. experienced 16 natural disasters costing over $1 billion each; and billion-dollar storms are on the rise[4]. Recurrent damage to cities and the cost of emergency response and recovery are a drag on the U.S. economy.[6] By the 2030s, the international community can't ignore the situation. They are dealing with climate change themselves and, perhaps, also with climate refugees from the United States who can't afford to rebuild and can't get help from their own government. Is it so hard to imagine concerted "development" efforts 20 years from now, initiated by concerned but ultimately self-interested allies in Europe and Asia? A balkanized political environment and an angry, resentful public are fertile ground for international investors to create cheaper renewable energy and sell it back to the American people along with the promise of the American Dream restored. FEMA, after all its practice cleaning up natural disasters, might be a welcome presence in cities, helping municipal governments manage for emergencies before they happen. Emergency becomes a trusted and effective player in local governance, supported by international friends concerned with their own wellbeing and anxious to make good in the land of opportunity.

Enter Detroit, PhoTown 2040. Here we see this modified international order connecting with the most local of U.S. governance

mechanisms, the homeowner association (HOA), where the once peevish, catty, and at times vitriolic HOA is recast as the hero of America's new energy future. It's poetic and it makes a weird kind of sense. HOAs are known for utilizing local democratic governance to squelch diversity, impose impractical aesthetic standards, and punish nonconformity, all in the name of preserving home values. Homeowners in suburban Houston, for example, were welcomed back from forced evacuations during Hurricane Harvey by notices from their HOA that their grass had grown too long[7], no doubt from all that rain. In "Under the Grid," HOAs are used to create seamless and efficient community energy systems within a physical structure (the Grid) built by the local branch of FEMA, with funding from Chinese and European backers. Neighbors band together and radically revise their Covenants, Conditions, and Restrictions (CC&Rs)—the rules HOAs use to ensure Camel and Brazilian Sand, but not Butternut Squash, are the accent colors allowed to adorn residents' homes. Newly rewritten CC&Rs allow HOAs for neighborhoods under the Grid to coordinate the local production of energy and food from solar panels and gardens neatly arranged in the skyspace above each home. The organization of the panels and accompanying features within the skyspace redefine communities and give them unique character. Sweaty, self-important little HOA boards seize the chance to extend their power, up, up, up into the air; well, at least up to 500 feet, less if you're close to an airport.

Not to be completely outdone by communities and cooperatives, Emergency deploys UN-sanctioned algorithms to guide HOAs and even individual residents in the efficient development of their skyspace. Local, national, and international government agencies and coordinated technology systems converge to maximize energy production, capture rainwater, ensure structural integrity, and preserve

biodiversity. The dance between local action and global influence is where much of the intrigue lies in this story.

Like Malka Older's 2016 science fiction novel *Infomocracy*, "Under the Grid" takes the quagmire of twenty-first century global governance seriously, challenging readers to consider what a renewable energy future might look like if it was built on current social and political structures. Perhaps HOAs could catalyze a transition to distributed solar power generation that makes money for communities. Perhaps the airspace above our homes, which is an extension of our private property, could be joined with those of our neighbors to generate utility-scale power above neighborhoods. In places like Phoenix, this could provide much-needed shade, while in wet, temperate cities like Portland, Oregon, it could help control rainwater and provide more space for urban farming. Bizarre, maybe, but there's no tabula rasa for the future … it will be built, in part, with what we've got right now. Democracies, even broken ones, have a tendency to take good ideas, chew them up, and spit them out in almost unrecognizable forms. "Under the Grid" shows us how, in the future, all politics is glocal—an inextricable fusion of global and local—and that might not be so bad for some well-masticated solar solutions.

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1. Jameson writes this in "Future City," (https://newleftreview.org/issues/II21/articles/fredric-jameson-future-city) an essay published in *New Left Review* in 2003, but he attributes it to an unnamed third party.

2. https://www.thebalance.com/u-s-debt-to-china-how-much-does-it-own-3306355

3. https://www.infrastructurereportcard.org

5. https://www.climate.gov

6. The National Oceanic and Atmospheric Administration (NOAA) has an ongoing project on the economic cost of natural disasters. According to NOAA the U.S. "has sustained 233 weather and climate disasters since 1980." The total cost of those disasters is estimated to exceed $1.5 trillion. You can find the project at https://www.ncdc.noaa.gov/billions.

7. https://www.chron.com/neighborhood/article/Houston-s-most-ridiculous-HOA-rules-12803240.php

Behind the Grid: Science, Technology, and the Creation of PhoTown

By Darshan M.A. Karwat

The Paris Agreement[1] didn't get the world all the way to limiting global warming to two degrees Celsius above preindustrial times. The world blew past that threshold in the mid-2030s; pockets of methane locked away in the tundra and released because of permafrost thaw[2] significantly accelerated the warming process. Global weirding[3] is what it felt like: unpredictable severe weather events abounded, and climate refugees[4] were as common as refugees displaced because of armed conflict.

In this turbulent global political climate, nation-states (yes, they still existed in the 2040s!) banded together to create the International Emergency Accord, which doubled down on the energy transition that began in the 2000s but also prioritized peace, which was significantly under threat given the instability caused by the climate refugee crisis. In stark contrast to the Paris Agreement, the International Emergency Accord had teeth to it—just like in decades prior when the World Trade Organization flexed its compliance muscles[5] through arbitration, adjudication, sanctions, and

penalties. The International Emergency Accord Court established by the Accord levied harsh sanctions on countries that failed to meet their mandated energy contributions.

When the United States failed to meet its obligations, the Court imposed its harshest ruling yet, creating Emergency. In many ways, Emergency was like any other environmentally and technologically oriented regulatory agency (like the U.S. Environmental Protection Agency), staffed by federal and contracted bureaucrats, managers, scientists, and engineers, and doing the same state-federal political dance that all regulatory agencies in U.S. had done. But Emergency was also the first U.S. agency accountable not only to the American public, but also to the Accord, which evaluated its successes and failures. The U.S. had five years to get each of its major cities to deploy enough solar energy to supply a significant percentage of the city's total energy consumption (think residential, commercial, buildings, heating, cooling, transportation, urban farming, any way you slice it). For Detroit, or PhoTown as the urban rebranding effort dictated, Emergency said that fraction needed to be 45%.

Over the preceding years, the revamped U.S. Department of Energy [6] had worked with the National Renewable Energy Laboratory[7] to develop a renewable energy deployment algorithm—based in large part on the Lab's Renewable Electricity Futures study[8] from the 2010s—that Emergency managers could use to help (coerce?) cities to develop their renewable energy plans and execution strategies. In the case of Detroit, planners relied overwhelmingly on solar energy to meet their energy target.

Algorithms had a tortured past[9] in big business and public policy, replete with well-documented racist[10], sexist[11], and colonizing tendencies, but there they were again, at the heart of important, long-term decision-making. Fortunately, the National Renewable Energy

Laboratory had created an oversight committee of social scientists, urban planners, and historians to provide strategic guidance on how its algorithm could limit, rather than exacerbate, social inequity and injustice.

Another leap in algorithm development—and an unexpected outcome of the National Science Foundation's Dynamics of Coupled Natural and Human Systems program[12]—enabled the renewable energy deployment algorithm to center biological diversity in energy transitions. While it didn't seem possible in the second decade of the twenty-first century, accumulations of scientific and technological prowess in the U.S. found their way into social policy in the third decade. The algorithm's inputs included:

- Urban infrastructure shapefiles[13] from each major city's planning commission for existing electricity, telecommunications, and water infrastructure
- Three-dimensional maps at sub-meter resolution of urban elevation, updated daily through SkySat[14] technology (because each city's skyspace changes constantly)
- Solar insolation[15] maps, climatological histories, and cloud cover data[16] from the National Weather Service
- Demographics at city-block scale and data about how the demographics have changed over time, from each major city's planning commission
- Details on local governance structures for each county in the U.S., based on political science and group dynamic predictive theories developed by researchers at Arizona State University and Wayne State University

- Biodifference and biodiversity[17] metrics, including ones related specifically to native and non-native birds, regardless of whether they were migratory or not (these were a product of a fruitful alliance between the National Audubon Society and the U.S. Department of Agriculture's National Resources Conservation Service[18])

And the algorithm outputs included:

- Renewable energy output of solar panels of different capacities as a function of height (up to 150 meters)
- Costs and payback periods of installing different solar panels as a function of height (up to 150 meters)
- Recommended support and scaffolding infrastructures in steel honeycomb, carbon fiber, and hybrid metal-fiber materials
- Minimum depth and width for the scaffolding foundation to safely support the minimum required solar energy installation and withstand changing weather patterns, as well as options to deploy more than the minimum required amount of solar energy, the electrical energy from which could be injected and sold into the grid
- Possible social, political, and governance ramifications of individual and community-level renewable energy installations

The algorithm guided how the Grid was designed, built, and maintained. Detroit in 2045—PhoTown—is the physical manifestation of that algorithm's insights. A 100-meter-tall superstructure supporting rapid energy transitions? Golly.

At the turn of the twentieth century, when the median hub height of wind turbines stood barely above 60 meters[19], no one could have

predicted the proliferation of stable superstructures covering a major American city. Marvelous advances in engineering transformed the if and for loops, the ones and zeroes, the numbers on a screen—the guts and outputs of an algorithm, mere possibility—into physical reality. Biomimicry did its part, and innovations from the wind energy industry did theirs. Inspiration from palm trees, those impossibly thin and tall ones that line the streets of Silver Lake in Los Angeles or the *Ceroxylon quindiuense*[20] from Colombia, coupled with new and low-cost carbon fiber "welding" capabilities developed for mega-scale wind technologies, helped PhoTown build the superstructure scaffolding for the Grid. The "welding" supports vertical structures, and is strong enough to create joints that allow for horizontal cross-beams to stay put.

Throughout its history, the U.S. had oscillated between bouts of intense protectionist nationalism and spells of promoting international liberalism, but the nation had never seen international political forces so deeply shape how it governed itself. PhoTown exemplifies how American ingenuity blossomed in this new world order shaped by climate crisis, with inventive thinking and creativity that blended imagination, design, and technology.

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Big Rural

TEAM MEMBERS

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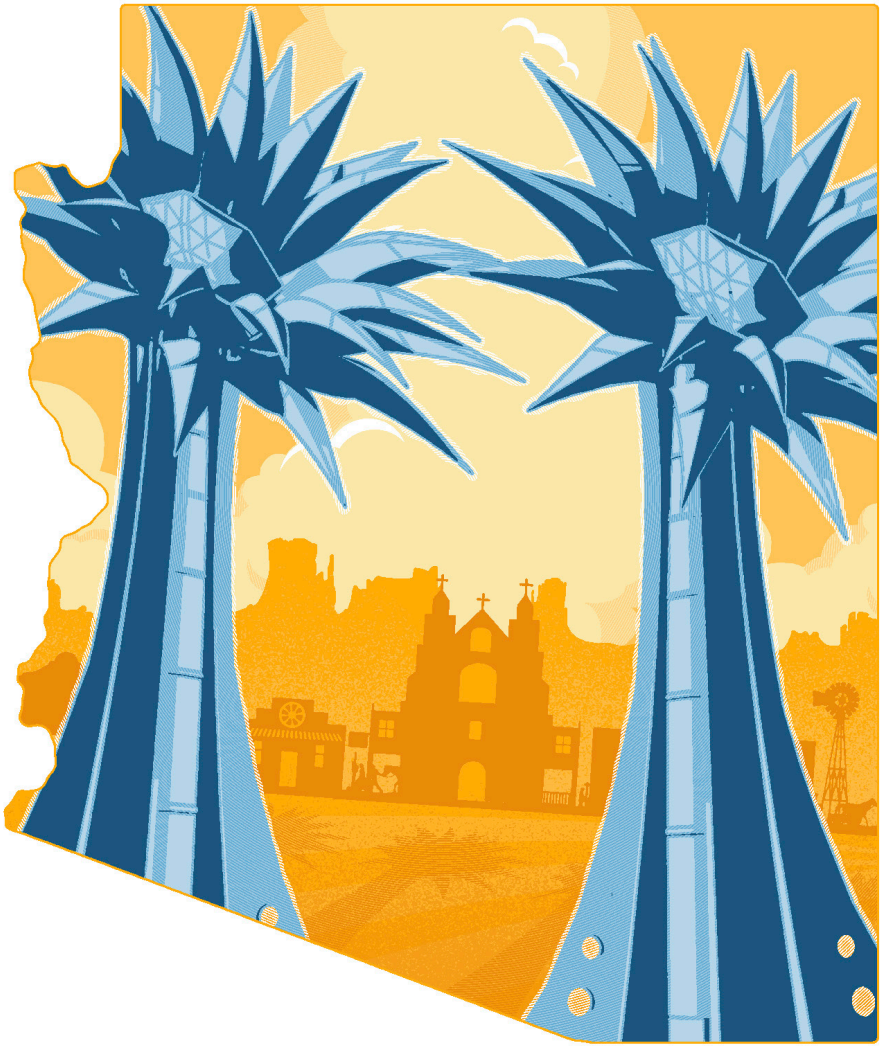
SOL DOMINION

PHASE II COMING SOON



BUILDING TODAY FOR A BRIGHTER

TOMORROW

Big Rural

By Cat Rambo

Trish almost didn't take the turnoff from Interstate 8. She was tired and anxious and it was easy to miss, particularly in the evening blast of last-gasp sunlight. A headache was building in the back of her neck, ratcheted up by lack of sleep. *Should have picked a self-driving car rather than this one.*

But when she glimpsed it, the decision to swing down the unnamed pebble-and-dust road that led to Ojos de Amistad Lookout seemed so natural that it was almost automatic, happening between one breath and the next. She switched off the AC and thumbed all four windows open. Almost as though she were back in high school, she and Jeff Garcia out driving his ancient Jeep in the early evening, when the blue ebbed from the Arizona sky and a faint scent of creosote rode the cooling wind.

If she got to the lookout point before the sun began to dip below the horizon, she'd see one of the best things about the valley. Because of the coal plant, Tierra del Rey had beautiful sunsets, and she wanted her return home to start with that image.

The road was barely car-width, even for her small rental. The car bounced and jittered along the road, sending pale dust and pebbles flying amid scruffs of agave and prickly pear. Tires crunching over rocks, the rumble outside battling the tinny sound from the

dashboard radio as the DJ segued into yet another country song. It was the third time she'd heard this one since pulling the rental away from the airport, a few hours ago.

You city people fill your lives with chatter,
Thinking that us country folk don't matter ...

The road narrowed and dwindled before widening out into four cars' worth of parking, unoccupied. She pulled the parking brake and reached to the radio.

But listen out here in the big rural, the big land,
Something's echoing here, maybe you can understand ...

She clicked the music off and grabbed her purse and water bottle before taking the footpath up to the point. The path had once been set off with railroad ties, which still bordered the sunbaked mountainside, but the cedar chips were gone now, not even crumbles left. Every step was a memory jabbing at her. How many times had she walked up this way, angry at something, someone, usually the town itself, full of resolution to get out, no matter what?

The sign at the fork was sun-faded into unintelligibility, but she knew what it said. Marcos de Niza, Spanish conqueror, had paused here, looked out, and claimed the valley in the name of his king. Also: no trash, no alcohol, no fires.

By the time she reached the ledge overlooking the valley, sweat covered her, and the evening breeze flickering across her skin was welcome, even if it was barely cooler. She went to the gym three times a week, but she wasn't in anything like the shape she'd been in

as a teen, when she was running track, knowing it the best chance she had for a scholarship. Running her way out of Tierra del Rey and into a better life.

One that had led her straight back here. Anxiety and guilt flared at that. What sort of welcome would she get? She hadn't thought she'd ever be back. Hadn't bothered to maintain ties. More efficient that way. More effective that way.

And easier. So much easier.

She gulped down the last of the water and stuck the bottle into her purse. The tomato-red sun rolled on the horizon, sending long black shadows walking across the land, towards the enormous black square that was Phase I of the Sol Dominion power plant, glittering in the last of the sunlight. You could barely see the storage structures scattered among the solar panels like enormous alien flowers, many-petalled and made of dark carbonized plastic with an oily undersheen of cobalt and purple.

Arms folded, she looked towards the town bordering that square to the east, where lights were flickering alive. She could name most of them. The gas station. The diner. The tiny grocery/hardware/drugstore locals just called "the store." The two-block strip that was Main Street, the grade school on one end, the high school on the other, linked by shared sports fields: baseball, soccer. Still no football stadium. The coal plant, unlit now.

When you came home again, even to "the big rural," as the song called it, things were supposed to have changed. Here the only change was that black square. Between the town lights and the scattered but symmetrical lights surrounding the plant, a dark strip, perhaps a mile wide, stretched, unlit. As though town and plant had turned their backs on each other.

Not all of them, though, given the vandalism she'd been called to investigate.

A mourning dove called, a lonesome *whirra-hu-hu* somewhere to her left where the cliff face stretched upward. She and Jeff had climbed further up dozens of times, but this spot had been their favorite.

She ran her thumb between her shoulder and the purse strap, feeling the leather cling to her sweaty skin. *East Coast life's* made me soft. She turned back to the trail and descended in the half-light while the dove called behind her. Halfway down, another dove answered it, and their solemn call-and-response accompanied her all the way back to the car.

By the time she was halfway back to the highway, full dark had descended. She switched on her brights, pressing the confirm button at the car's query. There were no other cars on the road, and she didn't bother to dim the lights until she hit the outskirts of town.

Two cars in the parking lot of the store. She didn't expect to recognize them, and didn't. The bell jingled the way it had a thousand times before as she stepped into the store's sallow fluorescent lights. Two customers talking to the clerk up front, one of those lazy shoot-the-shit conversations. Their backs turned. But then one shifted and the light hit his shoulder as he shrugged, showed the muscles along the back of his neck and she froze. *Jeff.*

She could have kept moving, but the customers looked around at the sound of the bell. Jeff recognized her immediately, she could read that in the way his expression shifted: surprise welcome then hardening into anger and a more defensive stance. Beside him, Aaron Paulsen. *Of course, who else would I least want to see the night I arrived? Aaron flippin' Paulsen.*

Behind the counter, a sleepy-eyed girl, high school age,

unimpressed and bored by all of them, stared down at her phone. Her name tag read *Zoe Z*, tilted at a careless 30-degree angle on the blue nylon uniform shirt. Trish remembered how scratchy that fabric was, how it seemed to gather heat in all the most uncomfortable places.

Jeff and Trish locked eyes. Aaron was the first to speak. "Beatrice!" he exclaimed, a little too hearty, a little too smiling.

She forced an answering smile, looking away from Jeff's accusing eyes to meet Aaron's chilly blue gaze. "Aaron. Jeff." Hefting a plastic basket from the pile slumped near the door, she stepped towards the back cooler cases. She was tired, and she was hungry. Get in, get the food, get out.

She expected them to say something more, but they were silent. *Trying to rattle me, that's Paulsen's style.* She felt that they must be watching, but when she swung around with her armload of milk, thaw-dinners, and a sleeve of eggs, Aaron was sliding money across the counter to the clerk and taking two packs of cigarettes along with a red, white, and blue striped lighter while Jeff stared at the lottery ticket display.

Aaron scooped up his change as she came up behind them. Turning, he said, "So, come back to check out what your company's been doing here?"

Of course they know who I work for, she thought. Small towns, everyone knows what everyone else does.

"Troubleshooting," she said briefly. She looked him in the eyes, watching his body language. "There's been vandalism. More than petty stuff." Jeff looked up at that, his face a careful blank.

Was that guilt flickering in the watery depths of the smile Aaron showed her?

"Yeah, I heard about that. People don't like the power plant. They

don't know what to expect. They know my family's coal plant built this town."

"They're saying a lot, seems like," she said.

He shrugged. "Small town, word gets around."

"Word of who's been doing it too, maybe?"

He shrugged. Behind him, Jeff's face still blank as an unlit screen.

They stood there in silence while she paid for her groceries and gathered up the bag.

"See you, Beatrice," Aaron said to her back as she left.

"I go by Trish now." On the door as she swung it open, a poster from Sol Dominion. The alien flowers dark and ominous against the blue and yellow of Sol Dominion, golden words above it: Sol Dominion Phase II Coming Soon. Underneath the picture in a more sober, shadowy blue: Building Today For a Brighter Tomorrow.

The bells jingled again as the door closed behind her.

She kept the windows open to the cooler night air as she headed to the solar plant. On its eastern side was the housing for the workers that had built it, mostly empty now but kept ready for the workforce that would return in three months for Phase II.

The moonlight washed out Sol Dominion's trademark sunshine yellow and sky blue, leached them of life until the trailers formed a symmetrical, boxy plastic ghost town. Their blank faces flickered past as she drove to the gate, a glass box, lit from the inside, housing a sleepy-looking woman nursing a coffee cup, reading a paperback. She glanced up as Trish rolled to a stop. Booted heels crunched over gravel; Trish turned off the car and proffered her ID. "Evening, Anita," she said.

Anita Luz, who had babysat Beatrice Soledad from the ages of three to seven, didn't acknowledge the greeting. She studied the plastic card before flipping it back towards Trish. "Any trailer's open except the first three in Row G." She made her way back to the booth and pushed a button. The chain-link gate shuddered open.

"Nice to see you too," Trish muttered under her breath.

Close up, the trailers in their identical rows seemed even spookier. They were all yellow with blue trim, the number beside each doorway the same color. She opted for Row F—one over but still close to the plant's other occupants, a skeleton crew of gate guards and technicians, totaling eight.

She settled in, unpacking her groceries. The trailer smelled of staleness and disuse and she opened all the windows, letting the desert breeze wash in and sweeten the air. There were no bed linens. She unfolded a t-shirt and dressed the foam pillow in it, then laid down on the crackling plastic film that covered the bed, listening. She could hear two owls hunting, calling to each other *huhu huhu* in a stuttering rhythm that overlapped then died away into silence then started again.

Quiet here. One of those nights when the wind sang in the telephone wires. Outside, the field of solar panels was silent and unmoving even as electricity flowed out of it, feeding needs far beyond Tierra del Rey. Sol Dominion's model project. Almost ready for Phase II. Whoever helped make that happen would be lavished with glory and bonuses and, most importantly, allowed a leap two or three rungs up the corporate ladder.

And if you leaped and fell? There were plenty of other young MBAs with gleaming degrees from Wharton and Harvard, ready to fall into line and begin their own journeys upward.

She fell asleep dreaming of ladders, reaching up out of dark water.

When she woke, the day was already starting to heat up. As she filled the coffee maker with water, she glanced out the window, then froze. One of the enormous solar storage devices was askew, canted at an impossible angle that threatened the arrays of black tempered glass beneath its long shadow.

One of the most important parts of the plant, the batteries stored the gigawatts then sent them out to power businesses and homes, so many lives dependent on that invisible flow.

Water ran over her hand as the carafe overfilled. She set it down, turned off the tap, and went out to investigate. The tower was one of the ones furthest from the worker housing and it took her a while to walk there. This close to the panels, she could see weeds growing in the shadows and spiny lizards lying in the sun, soaking up heat.

Machinery, hacked apart, the base of the alien flower chopped as though it were a tree. Beneath it, dropped as though the attacker had been scared away mid-swing, a long-handled axe. She knelt to examine it.

Most of the red paint had peeled away from the head, and someone had wrapped the handle first in string, then black electrical tape, so it could be gripped away. The pattern reminded her of how Jeff and the other boys had wrapped their baseball bats, emulating one of the older kids that year.

The security cameras yielded nothing; black hoods cloaked the faces of the three intruders, who registered only as collections of jerky motion in the infrared system. They'd disabled the lights beforehand; Anita had left a note saying she hadn't heard anything. Hadn't even bothered to wait to talk to Trish.

Bill Larson had been sheriff of Tierra del Rey for as long as Trish could remember. Stolid to the point of dourness, the lanky, balding man oversaw a single deputy, the pair based in a cinderblock construction on the main road into town. It was a tradition for the schoolchildren to paint murals on it. The current one was fresh, showing town buildings on one side, the solar plant on the other. They met around the central door, where the alien flowers shrunk, brightened, became marigolds, poppies, and roses.

She took a breath, squared her shoulders, and opened the door.

The air inside was crisply cold, hitting her bare skin the minute she stepped through. Lawson sat at his desk, facing the door, leaning back with his boots on the desk, coffee in hand as he studied some form. He scowled at the sight of her.

She shoved down all the feelings he roused in her of having done wrong. A fatherless teen with a mother working too many hours to watch over her children, she'd had her share of run-ins. Now she was here as Sol Dominion's representative; she stepped forward with the assurance that having a multinational corporation behind her in the face of a small-town sheriff gave her.

"There's been more vandalism, one of the storage towers," she said. "I need to see the other reports on it when you come to investigate."

Larson returned his attention to the form he'd been studying. "No reports. Company property, not town."

"You're supposed to oversee the whole valley!"

"Except for Sol Dominion holdings," he said flatly. "A pleasure to see you, Miss Soledad. Enjoy your stay here in Tierra del Rey."

Her head churned as she drove away. Aaron must be the ringleader. No one was more upset about the coal plant being shut down than the family that owned it, that had commanded a special spot in Tierra del Rey society as a result. She'd found plenty of Aaron's type in college and then Sol Dominion: born into wealth and unused to losing. They would do anything to avoid it, thinking themselves more deserving of victory than lesser souls.

She stopped at the store to pick up more water. The clerk didn't even look at her, too intent on her phone to care about any customer. On the way out, Trish saw the poster again. Someone had taken black felt-tip and scribbled all over it, tangles of dark ink, like weeds around the flower bases: "get the fuck out Sol we love coal" and "where's our water?"

Aaron, behind her again.

I forget that about small-town-in-the-big-rural. Every time you turn around, you're seeing someone you don't want to. His smirk, angled down at her as though to remind her of the height discrepancy.

"Come back to see what your company's done?" he asked, knife sharp. "Or to scavenge the corpse?"

"Corpse is an odd choice of word," she said, neutral. "The project's brought in jobs and money, with more on the way. What's dead, precisely?"

"Take your pick." Black felt-tip pen riding in his front shirt pocket, she noted. "Maybe the town. Maybe your friendships. Jeff everything you thought he'd be?"

He was, she thought, thinking of that expressionless face when he'd seen her. *Still familiar, same stance.*

She tried to steer them back to something closer to friendship. "Did he become a volunteer firefighter like he'd always said?" The firefighters had denied him as a teen because of asthma difficulties; nowadays with gene therapy she didn't think that would be such an issue, but who knew?

Aaron froze as though he was trying to figure out what she meant by the question, eyes narrowing. Finally he spat, "What do you care?" Pushed past and was gone.

She followed him though, at a distance. Trailed him back to the lookout. He'd lead her to the other vandals, sooner or later.

An unfamiliar car. She ghosted along, activating her net link—if she was discovered, she'd be broadcasting whatever happened, in livetime, deterrent enough for most criminals. And if not? *Something to think about when and if.*

She paused on the bend under the lookout to listen.

Aaron's voice, and Jeff's.

"Like a black hole," Jeff said. "Remember that from sixth grade science? That one always stuck with me, I don't know why. Big black hole, sucking up everything. Welcome to Sol Dominion."

She could see what he was talking about: the great glittering black puddle that was the project, the distant alien blooms, one of them askew. Inhuman. Swallowing life and giving nothing, a trickle at best, back to the town clinging to its edge.

But it was realization, not the vista, that froze her. *Aaron's not the leader.*

She thought of the long-handled axe. The sort a volunteer firefighter might carry.

Jeff is.

Walking back and forth that night, trying to figure out what to do. Every time she went near the guard shack, she could hear the radio. That big rural song again, twice.

You city people fill your lives with chatter,
Thinking that us country folk don't matter ...

To Sol Dominion, the townsfolk hadn't mattered. She remembered the presentation, the way they'd worded it. *Out in the middle of nowhere.* And her looking at the map, seeing the crossroads and realizing. *Tierra del Rey.*

Images flickered through her head as she paced. The poster, the angry black scrawls across it. The glittering black sea of the panels—there'd be so many more of them in Phase II.

But listen out here in the big rural, the big land,
Something's echoing here, maybe you can understand ...

The children's mural outside the sheriff's office.

The air chilled as she walked and the tears on her cheeks glittered as she paced.

She'd made a lot of calls by the time she invited Jeff to walk with her up to the lookout point. Cashed in all her social capital, maybe overdrawn some of it. That remained to be seen.

Jeff's expression was wary. He didn't say much as they walked side by side up the trail.

"Beatrice," he started once.

"That's not who I am. I call myself Trish now."

"That's not who I fell in love with."

After that, silence until they reached the point. Still a little cool, but sweat rode her forehead when they arrived.

She could smell dust and creosote bush on the wind. A red-tailed hawk swung far above in lazy spirals, getting an early morning jump on rodents and sluggish reptiles.

Jeff said, "I guess you know."

"I guess I do." She took out a bottle of water, took a swig, passed it over to him.

He drank and wiped his lips on the back of his arm before passing the bottle back. There were fine lines in the corners of his eyes now, years of sun she'd avoided. "So, what now?"

"Imagine if we made it something other than a black hole," she said.

He frowned.

"Ever hear of agro-voltaics?"

At his headshake, she continued. "Imagine crops growing between the panels, sheltered from some of the heat. Strawberries, melons." She searched her mind for the children's mural. "Marigolds, poppies. Even roses. The company took the water rights but hasn't done anything with them. I've confirmed that we can get most back."

She gestured at the expanse. "Yes, more space, but we've got plenty of that. And the infrastructure to ship the produce out at the same time. Send the power out to the state but feed it as well."

"That's a big change," he said.

She shrugged. "Some things are big enough to work toward."

The bottle was dry and sunrise well past by the time they finished talking.

"What made you change your mind, overall?" he asked as they

started towards her car.

She shrugged. “Thought about what would piss off Aaron most, so that meant nothing to do with coal.”

“No, really.”

“That’s as good a reason as any,” she said, but kept her smile tilted away from him as they walked away from the sunset and down the path.

Light and Shadows on the Edge of Nowhere

By Wesley Herche

A major theme of Cat Rambo's story "Big Rural" is socio-geographic perception: The story challenges the misguided notion that some places—in this case, a sparsely populated desert town—are "in the middle of nowhere." Truly isolated spaces are ill-suited for large-scale solar arrays, so we must seriously consider the rural communities that may serve as host to these supermassive-scale solar arrays.

A key source of conflict in the story is the concept of a rural versus urban divide. This divide is likely far greater in perception than physical space. Our protagonist, Trish, is challenged both personally and professionally to span this so-called divide between her rural community upbringing and her adult development and education within a major urban center.

The story also examines the challenges of perception in terms of the extraordinary scales that are commonplace in large-scale solar energy deployments. This challenge is often referred to as "trying to wrap your head around it." Many energy wonks and public thought leaders have pointed out that enough solar energy strikes the Earth to serve 10,000 times all human energy needs[1] across the entire globe. Another way people have tried to capture this enormity is by

pointing out that if you captured the sunlight that strikes the Earth in about an hour, you would have enough energy to power all of human civilization for an entire year.

These kinds of facts and comparisons often fall short of their intended impact, because our brains are just not evolved to think on these scales. Another common way people have tried to illustrate this point is by drawing a to-scale small square area on a world or national map and then stating the enough solar energy falls in that square to power the whole country. Even Elon Musk took the "this tiny square could power the whole country" approach at his 2016 keynote for the unveiling of the Tesla Powerwall residential battery storage device. These types of presentations often include a line to the effect of: *and that tiny square of solar could be anywhere; we could just put it out in the middle of nowhere and it would power everything.*

The problem with this rhetorical gambit is that it's not actually feasible to build a massive solar array "in the middle of nowhere." Granted, large tracts of uninhabited land exist—although that's already a very anthropocentric view in which we completely ignore the habitats of other species—but you need significant infrastructure in place to make building even a high-output solar array cost-effective. You need transportation infrastructure for trucks and other heavy equipment to get to the site, you need a water supply for maintenance and cleaning of the panels, and most of all, you need to have or build electricity infrastructure to transmit the energy you're generating out of "nowhere" to where people are going to consume it.

For many of our current large-scale solar arrays, small rural communities like the (fictional) town of Tierra del Rey in the story make for attractive locations. These communities offer proximity to vast swaths of open land, combined with existing transportation and utility infrastructure. The southwestern United States is ideal because it contains

a plethora of diffuse rural communities that dot a desert landscape largely devoid of human inhabitants, combined with some of the best solar potential in the world.

Even existing large solar fields occupy huge tracts of land that are geographically as big or bigger than the small communities that they are near. In "Big Rural," the existing Phase I solar array built by the fictional Sol Dominion energy company would be large enough to power a major city like Phoenix. For the proposed Phase II build-out, which provides the catalyst for the events of the story, we imagined an array that would provide enough energy to power the entire state of Arizona—with a 17% solar conversion efficiency rate, which is in line with the standards commercially available[2] today. Based on these assumptions, the Phase II build-out adjacent to the small town of Tierra del Rey would occupy approximately 48 square miles. That is more than twice as big as all of Manhattan (about 23 square miles[3]), or big enough to cover a major portion of the greater Phoenix metropolitan area.

In recent years there have been strong and growing sentiments among denizens of rural communities that they are being abandoned or somehow "left behind[4]" in the new hyperconnected global economy, which is predominantly driven from the urban mega-centers of the country. "Big Rural" supposes that we might once again call on these overlooked communities to house the energy generation required by our urban engines. The U.S. has a long history of locating power generation facilities in rural[5] and disadvantaged communities.[6]

To be clear, solar energy clearly has huge advantages over coal and other forms of fossil-fuel energy generation. It converts abundantly available sunlight into usable, clean energy without creating carbon dioxide emissions that poison the air[7] and drive global climate

change.[8] But expanding solar generation is not without challenges. For the United States and the world to make the necessary change to a fully decarbonized and renewable energy paradigm, the swaths of land that will be needed seem small at a global scale but will physically and culturally dwarf and envelop the small rural communities where they will likely be built. These facilities will dramatically transform the rural landscapes in which they are sited, potentially scrambling residents' sense of place, local identity, and connection to the land.

This makes the resolution in "Big Rural" paradoxical. When faced with the challenge of not being completely swallowed by this proposed behemoth solar array, the solution was an approach that actually takes up more land area! The plan proposed by Trish is to use a solar and cropland co-location technique that is a rapidly growing field of practice (no pun intended) known as agro-photovoltaics (or "agrivoltaics"). Agrivoltaics is an avant-garde practice and burgeoning field of research that has grown out of taking a more holistic and integrative approach to thinking about food, energy, and water systems. In some areas, agrivoltaics have been able to boost total land-use efficiency by up to 60%[9], meaning that more food and energy can be generated from a smaller amount of suitable land than from locating solar facilities and farmland separately. Researchers at Arizona State University have calculated[10] that using agrivoltaics techniques on the existing agricultural land in the Phoenix area could produce more than three times the energy needs of the entire metropolitan area. Since agrivoltaics is still a nascent practice, we took a conservative approach in our story and estimated that rows of solar arrays would need to be evenly interlaced with rows of agricultural crops. This doubled the size of the land needed for Sol Dominion's Phase II installation.

The agrivoltaic strategy proposed in the story is not a panacea. Rather, it is merely an example of the types of approaches that we'll need to consider in the face of escalating energy needs and intensifying climate chaos and resource uncertainty. This approach demonstrates how we might use design thinking[11] to tackle some of these challenges. Design thinking is a solutions-focused approach. Instead of trying to isolate and fix problems, teams instead work to build up ideas and potential solution sets in an iterative and organic fashion. Design thinking is especially well-suited to tackle so-called "wicked problems" (as opposed to tame or well-defined problems) where the challenges are beset with social complexities and system interdependencies. Our solutions will need to be both scalable and responsive to the social and cultural environments where our new clean-energy infrastructure will be built and operated.

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Designing Socially Relevant Solar Photovoltaic Systems

By Dwarak Ravikumar

In our group's story, "Big Rural," the energy company Sol Dominion's vision is to supply all of Arizona's electricity demand through solar photovoltaic (PV) technology, which converts the sun's energy directly into electricity, thereby eliminating our dependence on climate-intensive fossil fuel sources. Operationalizing a vision of this scale requires two critical resources: millions of square meters of solar PV panels and large tracts of land on which the solar panels can be installed.

Apart from helping Arizona transition to more environmentally sustainable sources of electricity, the large scale of operations entailed by this vision is also well-aligned with Sol Dominion's goal of increasing their profitability by reducing the costs associated with generating electricity from solar PV panels. This near-future strategy is supported by today's rapidly declining costs both of manufacturing PV systems and of generating electricity from PV systems as installations increase worldwide. Recent trends show that costs

for manufacturing PV systems at a commercial scale decreased from $7 per watt of electricity generated in 2010 to around $3 per watt in 2017. The share of electricity generated by solar PV sources increased from 0.1% to 1.4% of the total electricity generated in the United States during the same time frame.[1]

Given this trend, in "Big Rural," Sol Dominion initially favored a large-scale design paradigm in which a monolithic structure of solar panels is installed on the outskirts of Tierra del Rey to meet the electricity demand for the entire state of Arizona. The latest estimate for the total electricity demand in Arizona is 78 billion kilowatt-hours (kWh).[2] To determine the area of land required by Sol Dominion to meet this electricity demand through solar PV technology, we need to consider two key technical aspects: (1) the maximum solar energy that theoretically falls on Arizona's land surface, and (2) technical losses that decrease the amount of electricity that can practically be generated from the maximum available solar energy.

The maximum solar energy that theoretically falls on Arizona's land surface is 8 kWh per square meter per day,[3] which means that there is a potential to extract a maximum of 8 units of electricity per day from sunlight for every square meter in Arizona. Three categories of technical loss reduce the amount of energy that can actually be collected and processed into usable electricity: (1) the efficiency of the solar panels, (2) the losses in converting DC electricity generated by the solar panels into the AC electricity used by consumers, and (3) electricity transmission losses over the grid. Today's commercially available solar PV technology systems operate at an average efficiency of 17%, which means that only 17% of the solar energy available from sunlight can be converted into DC electricity.

Inverters, which are the main technology used in the market to convert DC to AC, have a conversion efficiency of 80%,[4] so 20% of the DC electricity being generated by the PV panel is lost in conversion to AC. Furthermore, 7% of the AC electricity made available by the inverter will be lost in the process of transmitting electricity over the grid from Sol Dominion's plant in Tierra del Rey to the point of consumption (whether that's a restaurant or school or apartment, etc.).

Accounting for the maximum solar energy that falls on Arizona's land surface and the three categories of technical loss, Sol Dominion's panels installed on one square meter of land in Arizona can meet an annual demand of 370 kWh. So, to meet a statewide demand of 78 billion kWh, Sol Dominion would need to install PV panels over an area of 209 million square meters (i.e., 78 billion kWh divided by 370 kWh generated per square meter) on the outskirts of Tierra del Rey.

Sol Dominion's initial plan to install an unbroken expanse of panels failed to account for the social dimensions and values of the stakeholders in Tierra del Rey. Given the conflicts, the technology design team in Sol Dominion adopted an alternative, more socially responsive design paradigm, agro-photovoltaics. The novel design features smaller circular solar panels that can be mounted on towers and co-located with cropland. Smaller PV panels provide shade and thereby positively affect crop growth. More importantly, co-locating multiple smaller PV panels in the fields necessitates more security staff to prevent vandalism and theft of PV infrastructure, plus a team of maintenance personnel to manage or address module damage or failures. This offers new employment opportunities for the

community and strengthens the partnership between Tierra del Rey and Sol Dominion.

We assume an area of 5 square meters to be ideal for the newly designed circular PV panels as part of the agro-photovoltaic system, which means that each panel would have a radius of 1.27 meters. Based on an area of 5 square meters per PV panel and an overall requirement of covering 209 million square meters with PV panels, the new design requires 42 million circular solar PV panels (i.e., 209 million meters squared divided by 5 meters squared). In addition, assuming that each circular PV panel will be mounted on a single support tower, the agro-photovoltaic design also requires 42 million towers.

Despite the increased number of towers, the novel design reduces social conflict (for more on this, see Wes Herche and Samantha Janko's essays in this book), provides opportunities for Sol Dominion to increase employment for the Tierra del Rey community, and reduces conflicts around land use by being co-located with cropland. In summary, the mutual benefits for Tierra del Rey and Sol Dominion will strengthen the project's prospects for success.

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Building Tierra del Rey: Design Features of Centralized Solar in a Rural Community

By Samantha Janko

To build the world of Tierra del Rey for the story "Big Rural," our group considered a litany of real-world issues associated with the design and implementation of solar power plants. At the heart of the story is the idea of centralized solar generation in a rural environment. These two design features for our vision of the future—*size* and *geography*—inspired the team to explore challenging and potentially contentious topics, including the importance of culture and community perspectives. We also drew inspiration from other design features, including *aesthetics*, *ownership*, *storage*, and *security*, which influence the attitudes and reactions of the Tierra del Rey community.

Many towns across the United States were established around coal mines during the late nineteenth and early twentieth centuries (Hazard, Kentucky, Sheridan, Wyoming, and Centralia, Pennsylvania, to name just a few). Many became ghost towns, but

in the ones that survived, coal is deeply engrained in the culture as a source of jobs, cheap electricity, and economic prosperity. Our team imagined Tierra del Rey as a farming town where a wealthy family opened a coal mine in the 1900s after discovering the resource was plentiful in the nearby mountain. About a century later, with the enticing promise of improved air quality as well as continued job security and cheap electricity for the town, the wealthy Paulsen family allowed Sol Dominion to purchase the coal plant at a loss and shut it down. In its place, Sol Dominion constructed their first large-scale solar project with some of the best technology available—large, high-tech solar-storage hybrid towers. After the success of Phase I, Sol Dominion moves forward with Phase II after a state mandate is enacted to meet all of Arizona's energy needs with solar. However, since the solar plant operates almost completely autonomously, the initial influx of jobs during the construction stage declined and the town largely returned to its agricultural roots, but now without the dependable energy-sector employment formerly available at the coal plant. The community begins to feel bitterness towards the solar plant and soon makes its displeasure known through vandalism.

The *aesthetics* of the solar plant are an important contributing factor to the conflict. Sol Dominion shaped the large, high-tech structures like flowers with a sharp, modern design. This design might work well in an urban environment, but sticks out as alien in a rural setting. Residents of Tierra del Rey find the towers foreign and unpleasant, marring their landscape and obstructing the view of their valley. This visual reminder adds to their growing resentment—the community doesn't feel *ownership* over the solar plant in the same way they had with the original coal plant that helped grow their town. Sol Dominion purchased the land for their own and built what they felt was attractive and cost-effective, without consulting

community members or being sensitive to their reactions. This element was inspired by modern-day wind turbine construction; many residents of communities where these turbines are built find them ugly and disapprove of them. In Primghar, Iowa, for example, wind farms are criticized by some locals as "noisy, over-subsidized eyesores that can be dangerous."[1]

The compromise at the end of "Big Rural" involves smaller, less visually intrusive solar constructions with softer edges, which suggests how communication and community involvement can improve attitudes towards energy transitions. The inclusion of agrivoltaics—the co-location of solar photovoltaic power generation infrastructure and crops—also creates a symbiotic relationship between the new solar technology and the traditional agricultural roots of the town. (For more on agrivoltaics, see Wes Herche's essay in this book.) In an agrivoltaic design, solar panels produce electricity while simultaneously supporting higher crop yields by providing partial shade for the plants growing beneath them.

Our team also incorporated issues of *storage* and *security* in creating "Big Rural." For large-scale, centralized power generation that will provide for a large population, the ability to store energy to utilize at different times of the day is crucial to ensure reliable electric service. As such, Sol Dominion included storage alongside the solar towers. This increases the amount of space required, but it's necessary for a full statewide transition to solar power. Additionally, physical and cyber *security* of power plants, substations, and transmission networks is a very real issue that leaves power infrastructure vulnerable to attack. In his *New York Times* bestselling book *Lights Out*, celebrated journalist Ted Koppel argues that the American power grid's highly customized power transformers are difficult and time-consuming to replace. This could result in a power outage for

weeks or even months at a time if grid control systems are hacked and used to damage components.[2] Additionally, substations are vulnerable to physical attack since they are typically unmanned during operation. The problem has been analyzed, but is far from solved.[3] In "Big Rural," community members in Tierra del Rey realize that Sol Dominion's Phase I plant is not well protected and find they can easily break into and vandalize the units. Increased onsite surveillance and physical security measures could help deter this type of crime.

We were inspired by real-world issues while crafting the setting of Tierra del Rey and the plot of "Big Rural." Issues around design features such as *size*, *geography*, *aesthetics*, *ownership*, *storage*, and *security* reveal that the implementation of new infrastructure technologies is a complex challenge. Infrastructure systems like energy generation and storage are the backbone of modern society and affect a large number of people when changes are implemented. As a result, even a change that seemingly promises only positive outcomes (such as plentiful clean energy) does not guarantee acceptance by all parties affected by the transition. To achieve success, designers must take the socioeconomic and cultural aspects of building new infrastructure as seriously as they do the technical and environmental considerations. Building infrastructure for a transition to clean, renewable energy is an investment in our collective future, but doing it right will require sensitivity to history as well—especially to the local histories of the communities that will see their economies and cultures transformed by these projects. Ensuring that our energy futures are just, not merely clean and efficient, means seeing energy as a collective, public endeavor: opening up design and planning to democratic processes and a plurality of voices, enfranchising everyone affected, and privileging the voices of those who are on the front lines of change.

1. Donna Eller and Kevin Hardy, "Is Wind Power Saving Rural Iowa or Wrecking It?" The Des Moines Register, April 20, 2017, https://www.desmoinesregister.com/story/tech/science/environment/2017/04/20/wind-power-saving-rural-iowa-wrecking/99789758.

2. Ted Koppell, Lights Out: A Cyberattack, A Nation Unprepared, Surviving the Aftermath (New York: Broadway Books, 2016).

3. Carl Herron, "Physical Security Analysis of Substations" (presentation, Northeast Power Coordinating Council Fall Workshop, Hartford, CT, November 8, 2017), https://www.npcc.org/Compliance/CW/Documents/Physical%20Security%20Day%202.pdf. See also "Guide for Physical Security of Electric Power Substations," an ongoing project at the Institute of Electrical and Electronics Engineers (IEEE) Standards Association coordinated by Erin Spiewak, https://standards.ieee.org/develop/project/1402.html.

Small Rural

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Divided Light

By Corey S. Pressman

"Tell us again how you came to the Oasis!"

"OK children, OK. Here we go."

The robed elder stood tall and made wide eyes.

"She pressed the cold blade against my sweating throat. I could feel my skin begin to split. The old woman looked down deep into my eyes. She seemed serene, calm in her violence.

"'Time to step into the light, young thumb,' she said.

"Just then it happened. A single thick drop, a liquid miracle, fell wet on her knife arm. Our four eyes darted to the spot. Another slapped my cheek, a sharp splash. The sky opened, children, and the water came down: a million impossible sparkling tears."

"No, Radrian! That's the end! Start at the beginning!"

"Forgive me, youngsters. As you know, I was not always a Ramish old one. So let us begin the right way. At the beginning, as you say. This is the story of how we divided the light."

Drawn

My friends and I headed out early; it was a few hours' ride to the Oasis from Shade City. We pulled out of town on the eastern expanse, through our dappled neighborhood, where the great solar shade that covered the central city offered the variegated light that

fetched high rents, touristy cactus labyrinths, and the best golf. Being young and offensive, we were sure to obey zero traffic laws as we sped through the outer city, where the shade ran out and our unfortunate neighbors wallowed in the dazzle of full sun most of the day.

We blazed out into open desert. Looking back, Shade City's solar ceiling dominated the horizon, reaching up and out as far as I could see. Looking forward, the Ramish settlements were almost invisible: small holdings dotting the landscape, a single slice of green the only clear indication of human habitation. Even the photon farms seemed to blend into the desert.

It was my eighteenth birthday, and we were headed to the Ramish Oasis so I could participate in a new but noble tradition: dunking my now-adult self in the deep Dragon Tree root pools at the center of the Ramish settlement. These desert denizens possessed some genius for biology and air: they engineered giant Dragon Trees that rooted to the aquifer and drew pools of cold water to the surface. The other source of Ramish water hung in the sky: a flotilla of tethered dirigibles populated by the Ramish aquateers of the stratosphere. Each mined the sky for humidity, one drop at a time, sloping the water down to glimmering oasis pools. These hosted a riot of chlorophyll that could be seen for miles.

I had never seen a body of water larger than a sink. I had never done more than splash myself with handfuls of lukewarm water. I had never immersed. Can you imagine, children?

We pointed the buggy at the winking green mirage ahead and partied hard as The Thumb grew hazy behind us. The Thumb—that's what we called Shade City, or, to be precise, the huge solar-panel sunshade that Umbra Corporation was erecting over town. The giant structure gave us life: it gave us cool shade and clean power. It

gave us a way to survive, and to attract people back to New Phoenix, which hadn't fared well in the flare years. But it also evoked a sort of dread. It was a hovering menace. It was The Thumb.

But not today.

Ignited

Tall clouds assembled in the distance and tucked into the northern horizon. This almost-daily assembly was new, and a cause for concern for some. This, and a recent rash of angry red haboobs. Some whispered a storm was coming, real rain. But that was ridiculous. No one here had seen rain in decades. And there was no way we were delaying our party for fear of mythical weather.

Not that rain wouldn't be remarkable. The lack of rain crafted our world, ours and that of our Ramish neighbors. The perennial drought was an active void, a creative hollow we filled with ingenuity, innovation, and life. Shade City filled the void with might—The Thumb was an engineering masterpiece that captured the sun and divided the light into raw power and chill shadow. The Ramish took more of a tinkerer's approach. With their photon-farming topographic technologies, everything they used carried its own power supply. Every artifact derived energy from the sun. And their biotech: hacking trees and hoisting balloons to divide water from the sand and air was pure alchemy.

A return of the monsoons would certainly rearrange our reality.

We were stopped at The Palm at the Edge of the World—the first tree since The Thumb. Beyond that leafy waypoint, we could see the bayou of biohacked Dragon Trees, sprawling photon-farm homestead arrays, and curving zeppelin tethers of the Desert Ramish. The Thumb, with its myriad mantis construction cranes, was now an inky smudge in the rising heat to the east.

The Ramish at the gate were guards: a few youths and an elder. She was a piece of work, this one. As the young guards asked us out of the buggy, she came our way, right to me.

"That was Goma!"

"Yes, yes, children. That was Goma. Although I did not know her at the time."

Like I said, she was a piece of work, a real Ramish mystic. Swathed in purple and green glowrobes, bright with captured moonlight, she got in close, enveloping me in that shine.

"This the young shadeling come to cross to old?"

She reached out her arm, streaked with shimmering sol tats, and touched my cheek. She smelled like water.

I did not move.

The Ramish were fairly liberal with whom they let in. Heck, they were openly recruiting in Shade City. *Step into the light!* sang their swarming folded-reed drones. *Join us at the Oasis and make the world!* But the old lady seemed like a decider, and being denied entrance on my birthday would be super thumby.

Holding my face, she closed her eyes, eyelids aglow with powdered yellow light, and mumbled a fragment of poetry from another century.

"Be ignited, or be gone."

We got back in the buggy. We were in.

Immersed

"Is that when you drowned?"

"Ha! Yes, it was pretty much right after we arrived."

We headed straight for the pools. It was my first time at the Oasis,

and it was overwhelming. The village was chaotic. And the colors! In Shade City, we all wore white linen tunics and lived in white-washed, low-slung homes. Here were flowing robes in a thousand subtle shades. The Ramish photon tech was legendary, but to see it in its native profusion was dizzying. Each garment, every face, every corner, wall, and vessel was aglow with patterns of harvested light bent to beauty. And the smell! The vast reed paddies emitted a sweet green musk you could almost taste: more magical Ramish engineering at work, this time in the novel field of photochemical conversion.

The pools were a common gathering place for the Ramish; a handful of them watched us with amiable suspicion as we stumbled from the buggy to the water's edge. Several offered the traditional Ramish greeting, *step into the light*.

Even standing ankle-deep in cold water was ecstasy. We yelped with false bravado as we dared each other to step deeper. But immersion was the goal here. I took a few wide sloshing strides and leapt in.

And that is when I drowned.

Not to death, mind you. But close. Of course, I couldn't swim. Few from Shade City knew how. And I had just slid into the deep end of the pool. The cold water surrounded me. I panicked and flailed and lost all sense of up and down. All I could see were bubbles, bubbles everywhere. My vision dimmed.

And then the light. Jelena's light. Her facial sol tats glowed a fierce gold as she carefully hoved towards me in the chaotic dark. There were arms around me and I was up and out. And in love.

She stood over me as I heaved up a week's worth of water. Her face swam in biografted color as the staccato song of the Ramish-made sun wrens surrounded us.

This was such a foreign moment—the almost dying, the edible smell, the swirl of biohacked birds, her tattooed gaze. Fascination

and fear. Right here was all the danger and strange that emanated from the Ramish, all the elements of their inscrutable otherness. Why would they engineer cells that way, with nanobio hybrids? Until then, I didn't, couldn't understand. To adapt yourself to the environment, rather than the other way around, felt like surrender to the flaring desert. The point of our city, our culture, in Shade City, was to keep people safe and free to live as before. We shouldn't have to biohack ourselves or our animals just to survive, to forge Frankenstein trees and spend our days mending cell, soil, and air. It was madness. A single simple bold creation—The Thumb, the latest engineering wonder of the human race—should be sufficient. Why this multitude of forms when just one would do?

But in that moment, I understood one facet of it for the first time: it was astonishingly beautiful. And hers was the most beautiful face I had ever seen. And still is, children.

"Thank you," I managed to croak.

She scowled a radiant scowl. "You are an idiot." This she said flatly. "You people are always getting in the water like you know what you're doing. This isn't some Shade City recreation facility."

She helped me up and wiped her hands on her wet turquoise robes.

"My name is Radrian," I said, offering my hand. By now, my friends were all around us, chuckling at my near-death antics and at this awkward exchange.

She didn't shake my hand, but was generous enough to give a small smile. "I am Jelena. Next time, stay in the shallows."

I didn't realize I was staring, mute.

"So, Radrian of Shade City, are you an adult now that you've done something publicly stupid?" Her gaze heated me up from the inside out. My heart tumbled wild. I heard myself speak.

"Uh, yes, I mean, no. Yes, today's my birthday. Listen, thanks, thank you. You, uh, live around here?"

At this, all of us laughed. My friends, Jelena, even me. It felt good to laugh.

"My, you're a smooth talker! Yes, you could say that. And you," she said, her hand on my arm, tilting her head in exaggerated flirtation, "... you come here often?" Her hand was rough and warm.

As I commenced the calculus for some witty response, we were interrupted by a shout from across the water. There, reflected in the still pool, was a tall Ramish woman, unmistakably a parent.

"Jelena!" she clipped. "Jelena! Come now. Help me get ready for the market!"

Jelena looked towards her mother, glanced back at me. Bit her lip.

And she was gone.

Entwined

We partied all the way home, our buggy recharged with the new bent-reed battery we exchanged at the edge of the Oasis. Aside from water (and, I then realized, Jelena), the reed batteries were the Ramish's best thing. These little woven miracles were constructed of genmod reeds that stored megawatts of potential energy when folded into complex condensed shapes. Set loose in a gearbox, the origami could power a buggy for days. Enough reed batteries and you could power your whole house with unmetered energy. The Thumb was wired everywhere in Shade City, even beyond, linking us to a grid that connected every house, every Umbra plantation in the desert, every desal plant on the Gulf of California eking out fresh water for food production and human consumption. The reed batteries, by contrast, let you disconnect, take your power with you, go wherever.

It was night when we got back under The Thumb. The Ceiling was transparent now in most neighborhoods, allowing in the starshine. Spotlights beamed down in some distant sector, illuminating a criminal on the run or a roadside stop, no doubt. Winking drones drifted on the Ceiling-fan drafts. The Ceiling in the club district was pulsing with some AR masterpiece or other. Some sleepier neighborhoods were dark, where the cool night air circulated in the full shadow of Umbra Corp's masterwork.

My parents were awake and waiting, lights on full. That meant trouble. We only used power at night during parties and emergencies. And this was no party.

They had learned where I was, that we had gone to the Oasis. My mom, a VP of something-or-other at Umbra Corporation and an upstanding citizen, was not keen on the Ramish. I had heard it all before: They were not like us. Their origins in Saudi Arabia proved their whole enterprise was un-American. They were freaks who distorted nature and were altogether unwholesome, unwelcome, and unsafe.

To my Shade-City-believer, die-hard-Umbra parents, the Ramish vision was anathema. The Ramish wanted power distributed throughout society, not concentrated in a single company or an enormous grid. They wanted to make their own food, via whatever hijacking and hacking of nature was required, not import organic produce from half a world away. Perhaps most importantly, the Ramish were evangelists, seeking to graft their vision to the soul of New Phoenix. They were a cult, stealing away Shade City youth and brainwashing the world. They didn't want Shade City to succeed or expand. And any Ramish achievement destabilized Umbra's long-term revenue projections. "Our very livelihood," as my mother liked to remind me.

Not everyone felt this way. Engineers and artists, young and old, often converted to Ramish: changing their names, receiving their sol tats, donning the robes of light. One day they were bored citizens, formatting voltaics for the Ceiling in a shaded Umbra lab; the next they were working the wonders of reed, bending or mining the atmospheric or subterranean aquifers for liquid gold. Even a distant cousin of my father went Ramish, *stepped into the light* as they called it. Now he crafts the genomes of marsh birds, carving phenotypes that capture water from the air and energy from the sun, bringing birdsong back to the shushed desert.

And there was the indispensable water the Ramish provided Shade City. And the reed batteries. And the amazing rainbow of photocycled garments and flowers and paints. When the Ramish first immigrated here from the Middle East, escaping the metastasizing, desert-eating gigawatt arrays of Riyadh's dune hinterlands, it was a boon. Really, Shade City couldn't exist without the Ramish.

My mom closed our argument that night with her standard summary of the situation: "Just because we can't live without them, doesn't mean we have to live with them."

Escaped

"Tell us about the fight in the market! How you saved her!"

"Yes, yes, children. That comes next."

The next week, on market day, I was working on the buggy when I heard a commotion. I peeked out of the garage and saw the smoke. The Ceiling was spouting thin streams of irreplaceable water at the fire. At the market.

I rounded the corner to the open white market square. Most of the place stood intact, piles of imported melons and racks of white linen

standing witness to the pocket of ferocity forming in the Ramish quarter.

Chaos.
Overturned stalls, spilling stacks of reed batteries, some of which unhinged far too rapidly, exploding with enormous energy, bouncing in all directions like giant fatal morningstars set loose from their chains. Sprays of lunar flowers scattered, casting a kaleidoscope of cool color beneath the rising smoke braiding thick above several burning stalls. Water jetted down over the whole scene, a perverse and pervasive inside rain.

The Ramish scattered, some trying to save their wares, others fleeing. One on fire. A knot of Shade City citizens toppled tables, rousting the Ramish. Yelling and crying accompanied the keening of approaching sirens. In the middle of it all, kneeling to collect the scattered glowing flowers, was Jelena.

Our eyes met. Even from that distance, in the smoke and confusion, I could see every detail of her face. Her fig-red lips, her green eyes, gold sol tats illuminating her wide forehead in the gathering gloom. For a second time, she offered me her small smile. Burning fragments of fabric and flowers arced slowly between us. Water descended, a fall of diamonds. The cacophony somehow dimmed. My heart slowed despite the panic.

And then I saw it: a market pillar behind her had unmoored and was careening, falling on Jelena. Children! You could imagine my terror! I was no brave soul, just a young fool. I tackled her just in time, both of us rolling away as the pillar collapsed in a flurry of fire and ash. Then we were running, me pulling her away from the chaos, away from the danger. Towards my house. I had to get her away from

here, out of Shade City. This was an orchestrated attack, a reverse riot designed to stamp out the Ramish menace. Jelena was not safe. Covered in cold sweat, we reached the buggy. We navigated around the burning market and headed east, out of town. We burned through the dappled districts and rocketed out from under The Thumb and into the full sun. Neither of us breathed a word until we hit the desert.

Found

"Thank you," she croaked.

"I'm so sorry, Jelena. I can't believe this happened, is happening. I know some folks aren't happy with the Ramish, but this is crazy. Who would attack a market?"

"It all happened so fast," she said. "And you all look the same in your white linens." This, with a bit of disdain. "One second I was arranging photon-flower bouquets, the next there was an angry knot of thumbies, then shouting and toppled tables and loose batteries. Then fire. Then you." She tilted her head onto my shoulder, a frightened bird on a frightened perch.

"Well, we're out of there now. At this speed, we can get you to the Oasis in an hour. Although this may be the buggy's last ride; the battery is new, but the gears are old. Either way, you're safe now."

"Is that when the farmers found you?"

"Yes children, it was not long before we were radioed by the Ramish caravan. The very angry Ramish caravan."

"Hey! Thumb-sucker! What's the hurry?" The message startled us both. I looked around—at this speed, there was no way any vehicle could sneak up on us, Ramish or Shade.

"Uh ... this is Radrian from Shade City. There was an attack, a, uh ... fire at the market. We escaped ...."

"Listen, friendo." Whoever said this had a thick Ramish accent, sort of Saudi meets Scottish. "We know about your attack. And now we see you burning towards the Oasis. To finish the job, eh? Well, I don't think so."

Where was this guy? There was no one behind us, no one in the desert at all. Just the hazy Thumb behind and resolving Oasis ahead.

Then it was dark. A wide shadow inked over us. I pulled back the roof flaps and there was the great grey ribbed belly of a Ramish zeppelin. The mammoth multifoiled airship cruised a thousand feet above. And it wasn't alone. Looking up and around, we could see that this was the lead ship in a collection of dirigibles of different hues, shapes, and sizes. This was a Ramish caravan, come to truck water and wares. And to stop us.

"I recommend you put on the breaks, hotshot. Would hate to waste a whole heavy crate of spirulina dropping it on your ugly little buggy."

Up ahead, The Palm at the Edge of the World came into view. Three Ramish buggies sped out of the compound. Like everything else Ramish-made, they were painted in festive photo-paints, designed to absorb and emit. These surfaces powered the buggies and adorned them. I never knew coral pink and powder blue could look so menacing.

I toggled the radio to all freqs. "This is Radrian from Shade City. I am with Jelena—we escaped the market attack. I'm bringing her home. Please, I'm stopping now."

I slowed the buggy down. The desert dust fanned a high tail behind us as the wheels bit into the sand.

"Jelena? Is this true?" It was an old woman's voice on the radio.

"Yes, Goma. It's true."

The zeppelin above slowed with us, the nose dipping. Its front hatches slid open.

Jelena continued, talking fast, voice trembling. "It's true. It was terrible, Goma. They set it all on fire. They broke everything."

We came to a stop just as the three Ramish buggies skidded in to surround us. Jelena and I got out as the guards rushed in. Caravan truckers were thumping to the ground around us, unclipping from their long bungees as they hit the ground. The dust from the skidding buggies dangled down, enveloping us and shifting in the rising breeze.

We were surrounded by a knot of glowing guards and sky truckers. They were moving in slow. Knives out. Somebody's radio squawked news or orders.

Jelena took my hand. This stopped them. We all stood blinking in the dust. The breeze picked up and shifted the Ramish robes in the silence. The sky seemed to dim. The crowd parted as Goma strode through, scraping her blade from its place on her hip. She drew to a full stop before us, eyeing our clasped hands.

Her tone was almost conversational. "Jelena, darling. Please step away from our … guest."

Jelena shook her head, grasped my hand tighter.

Goma shifted her gaze to me. The breeze stiffened and flew her hair like a long grey banner.

"Twenty Ramish," she said. At this, the crowd seemed to shuffle in closer, straining to hear her above the moving air. "Twenty Ramish died today in Shade City. Those who tried to escape were chased down and murdered in the blaze districts."

The crowd inched in. And not to hear better.

"Jelena, love. Please come here." Even with all the whipping sand

and flapping robes, I could see her hand tighten around the hilt.

"No, Goma," Jelena replied, shaking her head. "Please don't. Radrian saved me, wasn't involved in the violence."

Goma moved very quickly, children. She came at us, pulled Jelena away and behind her. Jelena was absorbed by the wall of wind-strewn robes.

"Not involved? Why, isn't this the very child who came through here last week? Who, despite my generous blessings, treated our pools like a playground? Isn't that just the sort of *involvement* that led to this rampage? And their police did nothing. And no thumb blood was spilled. Until now."

My back against the buggy, she had me.

She pressed the cold blade against my sweating throat. I could feel my skin begin to split. The old woman looked down deep into my eyes. She seemed serene, calm in her violence.

"Time to step into the light, young thumb."

Just then it happened. A single thick drop, a liquid miracle, fell wet on her knife arm. Our four eyes darted to the spot. Another slapped my cheek, a sharp splash. The sky opened, children, and the water came down: a million impossible sparkling tears.

"That was the first Bloom, wasn't it, Grandmother?"

"Yes, children. And it was spectacular. The desert sprung to life. Later, the caravaners said that, from their high zeppelin vantage, the desert looked like a vast Ramish tapestry. They had to squint to pick out the Oasis and the Thumb amidst the profusion. This was the great lesson that set us on our current course of cooperation. This was the moment we all felt small enough to be indivisible."

At first the rain shocked us into stillness. We stood astonished, tilting our faces to the sky. Our reverie was interrupted by a groan

from above; the lead zeppelin dipped and rotated like a sick animal. The great skycraft started limping towards the sky harbor above the Oasis, followed by the others. Each wobbled under the weight of the impossible rain, its photon-powered hydro-extractors overwhelmed by the deluge. Then everyone was on the move, getting in buggies, heading for shelter, heading for home where the photon farms were already flooding. Their shouts were reduced to susurrus beneath the shower's steady hiss.

Jelena found me in the riot of robes and rain.

And she took my hand.

Choices

By Clark A. Miller

Cities change slowly, if at all. The 1950s choice to make Phoenix into car city, a giant grid of thoroughfares, endures today in its cookie-cutter housing developments, Walmarts, and Walgreens laid out in predictable patterns across the Valley of the Sun. But what if the city had to choose again? Would it take the same path?

The beating heart and circulatory system of any city is its energy infrastructure. Energy enables and informs urban design, both materially and socially. It shapes how far and fast people travel, how extensively they transform their environment, how widely and thoroughly they draw nets around the food, water, and resources of their neighboring hinterlands. Energy technologies organize everyone and everything, from political economy to the routines of everyday life. Humans are not so much what we eat but how we convert energy into action.

Phoenix in the 1950s was the brainchild of the Del Webb Corporation, the original Sun City, a place where ordinary people could retire to an active life of fun in the pool and on the golf course, the suburb of tomorrow in the making. But it was also a place where people dreamed the future of the city very differently. The legendary architect Frank Lloyd Wright came to Phoenix every winter, his students in tow, to teach them to live in and to design according to nature. Taliesin West, his home just north of Phoenix, is an homage to that vision and a product of his own and his students' ideas and hands. One of Wright's students, Paolo Soleri, settled in Scottsdale with dreams of creating a new utopia, Arcosanti, a perfect marriage of people, technology, and ecology, cultivated under the desert sun. Wright's and Soleri's visions never really caught fire, fading in the harshness of the relentless, baking heat, but they provided an alternative, critical gaze that continues to reverberate today in the persistent—but wrong in many ways—view of Phoenix as the most unsustainable city in the world.[1]

Surprisingly, to many, the denizens of Phoenix use less electricity than most Americans. They do a better job of recycling and reusing water. They drive their cars no further than the national average on a daily basis. All of these facts run counter to the narrative of Phoenix as particularly unsustainable. That narrative stems from two fallacies. The first is about air conditioning. Introduced to mass culture in the 1950s, air conditioning is a symbol of modern convenience—or excess, depending on your point of view. But it takes significantly less energy to cool a Phoenix home when it's 120 degrees outside than it does to heat a home in Chicago when it's 0. So why does our culture

consider air conditioning an unsustainable luxury, while heating is an unavoidable necessity? The second fallacy concerns the vast technologies that sustain Phoenix. Phoenix is brazen about its dependence on technology, making no bones of the fact that it moves water hundreds of miles across the desert to slake its thirst. As such, it is highly exposed to disruptions in supply chains. Yet, in this respect, Phoenix is no different than any other U.S. city. All cities today rely on global technological systems to provide food, energy, water, and materials. None are exempt. New York ran out of fuel during Hurricane Sandy. San Juan suffered the longest blackout in U.S. history after Hurricane Maria. We are all vulnerable. Phoenix just wears its vulnerability a little more visibly than other cities.

Phoenix stands on the precipice of the future. Old energy—the giant, world-spanning energy systems that made Phoenix possible, pumping water over vast distances, moving people along Route 66 from Chicago to Los Angeles, air-conditioning the desert—is under the gun. Carbon has to go, full stop. Internal combustion engines, gas turbines, and coal-fired power plants are stranded dinosaurs, dying the slow death of extinction. So, too, the old weather that drew privileged white people to the Valley. Climate change is making the desert even hotter. Water is slowly evaporating from the Colorado River. "A hundred days over a hundred" is becoming "a hundred and ten over a hundred and ten." It's a precarious situation, and it's set Phoenix politics and social life on edge.

As Corey S. Pressman's story "Divided Light" hints, Phoenix in its current form may not make the cut. A whiff of meaningful change, and people might hesitate before moving to town. A recent Rolling

Stone exposé on climate refugees inside the United States identified individuals who've already left the city over its rising temperatures.[2] A trickle could turn into a stream, and then a flood, just as the waters wash across the landscape during the monsoon.

Shade City is the direct descendent of Sun City. Its *raison d'être* is relaxation in a resort-style bubble, insulated from the harsh desert environment by a smart-glass, photon-hacking, quantum conversion barrier with a wide array of technological capabilities variously called The Shade, The Ceiling, and The Thumb. The Shade's panels can shift from transparent to opaque to translucent, dividing the light, dappling the surface beneath, creating patterns of starlight and moonlight never before seen in the night sky. It's a constant work of art, carrying the colors and lines of saguaro and organ pipe cactus gardens into the clouds, even as its shimmering hues contrast the monochromatic simplicity of the dense, multifamily housing structures, golf courses, and shopping malls below. Shade City is present-day Phoenix taken to an extreme, a socio-technical system so thoroughly techno-encapsulated that you barely notice the nature outside the 10-kilometer-square fishbowl created by The Shade. It's an illusion, of course, heightened by the long-term drought that has banished the monsoon and with it any hint of rain on the glass roof. Yet, it's an illusion that's pretty darn compelling for those who live under the Thumb.

The Shade's high-efficiency photon capture devices collect most of the solar spectrum, reflecting the rest into space. The output is vast

energy resources for Shade City. At 35% efficiency, the Shade produces 300 times the energy needed by the city's residents to power their homes. Electrons are cheap and abundant for everyone. Shade City denizens don't just enjoy central air conditioning in their houses; the city keeps the daytime temperature cool under the entire canopy. Biolights feed their cactus gardens, and people float down the golf course or across town to the mall in their Boeing electric, hex-a-rotor aircaddies. Their answer to the constraints of life in the desert? Move stuff, long distances if necessary. They move power from The Shade to the city itself through a giant central stanchion (The Thumb). So, too, they move that power to the city's desalination plant on the Gulf of California via enormous, high-voltage DC transmission lines. The newly cleaned water—and the salt, separately—come back in giant electric caravans, along with shipments of food from the city's vast Sonoran plantations, running along electrified guidewires tied into the new regional super-grid. The Shade is not just art or shade or ceiling; it is the infrastructural pump for energy networks that flow downward and outward from Shade City across millions of square kilometers of desert landscape. The result of all that infrastructure? As the billboards announce: the power to live the perfect life of comfort, convenience, and security.[3] A life of ease, as our protagonist makes so abundantly clear. No worries, be happy. Play golf, enjoy a walk in the cactus gardens, take a nap in the shade.

The Ramish are a different shade of light altogether. They are disciples of a generation of ambitious—and perhaps a bit mad—scientists and engineers lured by the cash liberated by the sale of Aramco and the rush of innovation spurred by Saudi Arabia's

Vision 2030, the Kingdom's effort to transform itself from a petrostate into a center of Islamic technological and cultural entrepreneurship and exchange.[4] The Ramish are techno-entrepreneurs, libertarian craftspeople, inexorable makers, luminosity artists, and desert smallholders who make their living hacking quantum-conversion technologies as sources of income, and of beauty. Their ideas initially took shape in a tent city set up in the sand dunes halfway between Riyadh and Masdar City, before they were pushed out by growing arrays of solar panels gobbling the Arabian sands. Their culture internalizes, rather than externalizes, the food-energy-water nexus. They produce their own, rather than importing from other places. They are photon pharmers, protein engineers, and water miners. And they are lightsmiths and reed-benders, sculptors of high technology who forge photons into every conceivable form of energy service the Ramish need or can sell to their neighbors. Like the leaves of desert plants, like palo verde trees or creosote bushes, their devices transform light via molecular design into a vast array of chemical and physical phenomena that do work—and create splendor—for humankind.

Ramish technology is something to see: "batteries" made of reeds that bend in on themselves, unfolding to release potential energy; luminescent inks that impregnate the epidermis, creating permanent new cellular luminescence for sol tats, tattoo markings that signal an array of social, cultural, and familial information; sunbirds such as raptors, herons, and wrens with photoreceptive feathers that take in sunlight and convert it into food and water; dragon trees

with roots that penetrate rock to vast depths and desalinate brine aquifers to create potable water; dirigible skins that use photons to coax water from the dry desert sky.

Ramish culture is decentralized. Their holdings are small and scattered across the desert. Dirigibles, photon pharms, and dragon trees are usually family-owned businesses. So, too, light forges and bioartistry co-ops. Families are arranged professionally in guilds and genealogically in loose kinship networks. Groupings of smallholders are arranged around Oases—literally places that store water, but also places of gathering, worship, commerce, and intrigue.

At the heart of Ramish political economy are the practices of making and valuation. Making is the act of creation, of the bringing of an object, an event, or a person to perfection. The Ramish greeting "Step into the light" is an invitation to forge oneself, to see the potential within oneself, while also being forged by the community into a disciple of the light: to declare one's intent to be remade into a maker and to subject oneself to the process of making. Makers are material foundries: transformers of the basic elements of Earth and water and light and life into the material foundations of societies.

Valuation is the accounting for use: an assessment of whether innovation enhances or undermines the thriving of individuals, households, businesses, communities, and societies. The great mistake of the Silicon Valley juggernauts of the early twenty-first century was to forget that the ultimate source of value creation is

people's ability to use technology productively. Modern business models too often focus on creating value for the business, not for the user. Yet, if users cannot use a technology, first, to create value for themselves—and not just any value, but real value, net of the burdens or risks of use—then that technology will inevitably create a drag on its users, sapping income or wellbeing and undermining thriving.[5] This can occur even if customers seem willing to pay the price for the technology. Some utilities in poor countries give away televisions when they hook up new customers to the grid, because they know they'll pay their bills, even if it costs their last dime, not to have their TV cut off. Valuation is, by contrast, an attempt to reverse that cycle through patterns and practices of reinvestment that trickle value in rather than out—to find ways to ensure that new technologies create real value for their users.[6]

For the Ramish, valuation is essential. Ramish technologies empower their users, nurturing value creation, looping generative feedbacks that strengthen communities. They are instruments of human thriving, wrought with thoughtful care to work sunlight into human creative possibility.

Choice is what makes the future. Or rather choices. Lots of choices. Individuals, families, businesses, organizations, governments: each chooses what to see and how to see it; how to understand and frame problems; how to respond; what kinds of values to commit to; what kinds of possibilities to imagine and strive for; what policies to adopt; what to buy; who to buy it from; how much to pay; how to use what they buy to create value for themselves, or not. Taken together, all of these choices add up to create the tomorrows that everyone inhabits.

Perhaps it is this indeterminacy—no one's individual choices shape the future alone—that leaves us feeling disempowered. No one need be responsible for the future, if everyone contributes only a small bit to its making.

Yet, there are also big choices. Recently, an influential political leader declared a preference for a future of plentiful solar energy in Arizona, while also suggesting that the state should obviously want the solar future that would be the least expensive.[7] As the story of Shade City and the Ramish suggests, however (alongside all of the stories in this book), the cost of future solar systems is hardly the only design choice that matters. For Arizona, and for Phoenix, choices about how to arrange solar systems on the land, how to arrange their ownership, in what ways to make them beautiful, or whether to partner them with transmission networks or storage systems are just as important as cost. Energy is the lifeblood of modern societies. As such, choices about energy systems determine far more than just how we produce and consume energy. The future of many aspects of Phoenix is at stake in how we choose to design our solar energy future.

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1. For a representative example of this argument, see Andrew Ross, Bird on Fire: Lesson's from the World's Least Sustainable City, New York: Oxford University Press, 2011.

2. Jeff Goodell, "Welcome to the Age of Climate Migration," Rolling Stone, February 25, 2018, https://www.rollingstone.com/politics/politics-news/

welcome-to-the-age-of-climate-migration-202221.

3. Our imagination of Shade City is indebted to Abraham Tidwell, who describes in his dissertation, "Morals in Transition: Imaginaries and American National Identity Through Three Energy Transitions," and particularly Chapter 5, the sales cultures of green energy living in the retirement communities of the Phoenix West Valley.

4. For more on Vision 2030, visit the Kingdom of Saudi Arabia's official website for the plan: http://vision2030.gov.sa/en.

5. See Clark A. Miller, et al. "Poverty Eradication through Energy Innovation," https://ifis.asu.edu/sites/default/files/general/miller_et_al_2018_asu-ae4h_poverty_eradication_through_energy_innovation.pdf.

6. Jameson Wetmore has written eloquently in "Amish technology: reinforcing values and building community," in IEEE Technology & Society, about the ways in which Amish communities are highly deliberate in their introduction of new technologies into their societies, making sure that those technologies fit their values and their preferred ways of living and organizing community. Crucial for the Ramish is the insistence that this exercise of valuation is a responsibility of the maker and not just the user.

7. "Commissioner Tobin Proposes Comprehensive Energy Reform," Arizona Corporation Commission, January 30, 2018, https://www.azcc.gov/Divisions/Administration/news/2018Releases/1-30-18Commissioner%20Tobin%20%20Energy%20Reform.asp.

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