In a world of Energy Mainframes, our “PC, meet the Internet” moment is very close.

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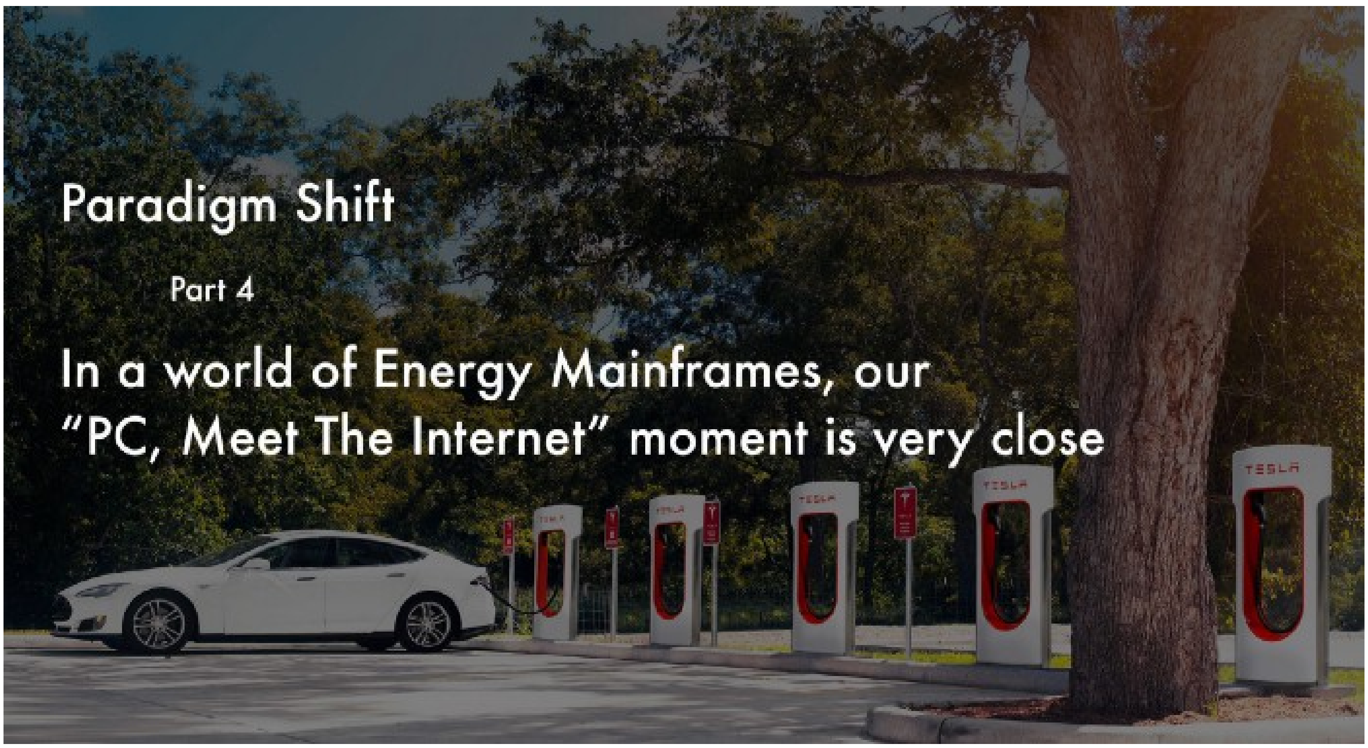

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Welcome back. In part 1, we covered a general framework for how to make sense of paradigm shifts in the world. This section, although it covers its own topic, can be read as a continuation of part 3 (Our shift from a driver-centric to a car-centric culture).

Welcome to the final part of this series, which is going to cover a lot of topics: energy, the Internet of Things, cars, and more. This will be the longest and furthest-reaching post of this series, so I humbly ask for your patience as we work through what’s going on. I promise it’ll be worthwhile in the end.

Just as in last post, I’d like to open with a broad question to anchor the discussion. Imagine you could go back in time to the mid 80s, as early online services like Prodigy and Q-Link were in their infancy and personal computers were in their last isolated years of being overshadowed by the big Wang and DEC machines. Imagine you could share a message with anyone who’d listen about what is about to happen: the only rules are you can only say one sentence, and you can’t mention any companies by name. What would you say? Here’s what I would say: *When personal computers come online, the world will change forever.* We may be close to a similar moment for energy.

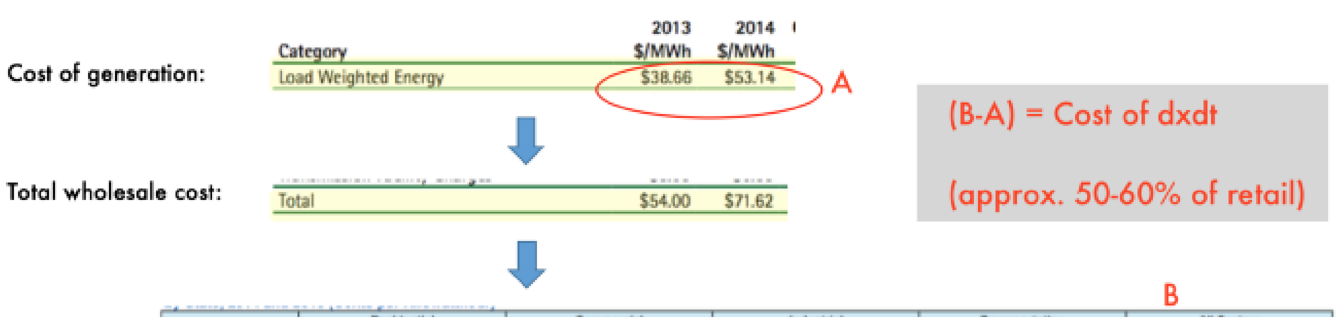
Last post, we talked about the on-demand and autonomous aspects of transportation, which are quite fun to think about as they contained two of our paradigm shift steps in series with one another. Electrification is also going to be difficult to work through, but in a different way: because there are two steps, going on *in parallel*. Fortunately, if we take our time and untangle the various threads in question, we can actually see a clear possibility of what will happen.

In order to get there, we must start in the past, prior to when we harnessed electricity. During the Industrial revolution, energy was a very scarce resource. We’d figured out how to harness kinetic energy (through water power) and chemical energy (by burning fossil fuels), but with a strong limitation: you had to consume that energy right then and right there. “Live” joules of energy were scarce — if you had one on hand, right now, you could use it. But otherwise, you were out of luck.

Around the turn of the 20th century, we developed a new capability: to transform that energy into electric current which could flow through wires. This unlocked a very important new possibility: to consume energy elsewhere from the power source. Then we took a step further: we organized those wires into an electrical grid, enabling many different power plants to serve a distributed group of customers. Consumers gained a second freedom — to use energy at the time of our choosing, as any one customer was no longer dependent on a specific plant being online at any given moment. These two new powers — freedom of place and freedom of time to consume electricity, so long as you were plugged into the grid — dramatically increased what could be done with a joule of energy. Funny enough, we don't actually have a succinct single word to describe this combined effect: *the ability to consume a joule of energy at the time and place of your choosing.* So I'm going to abbreviate that concept as "dxdt" for this argument, which you can think of as a single quantity representing "place-shift-time-shift".

The following point is important to understand: from any user's point of view, *you can't really separate the dx (place) and the dt (time) components of dxdt.* So long as you are connected to the grid, it does not matter where or when you turn on your light switch: it will go on. This is why you sometimes hear people well versed in energy say "The grid is a battery." It's not literally a battery- but to any observer, it acts like one. For anyone putting energy into the grid, you don't have to worry about who's consuming it when or where; for anyone pulling energy out of the grid, you don't have to worry about who produced it, when or where. The lights go on, and that's that.

How is this the case? Because grid operators do a lot of hard work to make sure the system is always in balance. The grid is like a bathtub, always filled exactly to the brim, no more no less. Pulling off this balancing act is no small task: it requires constantly monitoring your load, maintaining transmission lines, bringing new plants off and online, and keeping extra capacity in reserve. This is all expensive — about 50 cents on every dollar of our electricity bill go collectively to these various dxdt functions. But we pay this money for a good reason: were there no dxdt, we'd be brought back a century: each of our homes would have to be directly hooked up to a local power source, and our ability to turn on the lights would be subject to that plant being online here and now. Hence, dxdt is a very valuable thing.



Census Division and State	Residential Year 2014	Residential Year 2013	Commercial Year 2014	Commercial Year 2013	Industrial Year 2014	Industrial Year 2013	Transportation Year 2014	Transportation Year 2013	All Sectors Year 2014	All Sectors Year 2013
Pennsylvania	13.32	12.79	9.73	9.25	7.41	6.97	7.65	7.8[illegible]	10.28	9.81
East North Central	12.65	12.14	10.02	9.58	7.07	6.65	7.10	5.61	9.85	9.40

All together, dxdt accounts for more than half of our energy bill. (PJM / Pennsylvania, 2013–2014)

This brings us to our next important point: the grand bargain of energy in the 20th century. As we’ve said before, the grand bargains represent those great compromises between scarce resources, around which an industry sits at equilibrium. In energy, what has it been for the last hundred years?

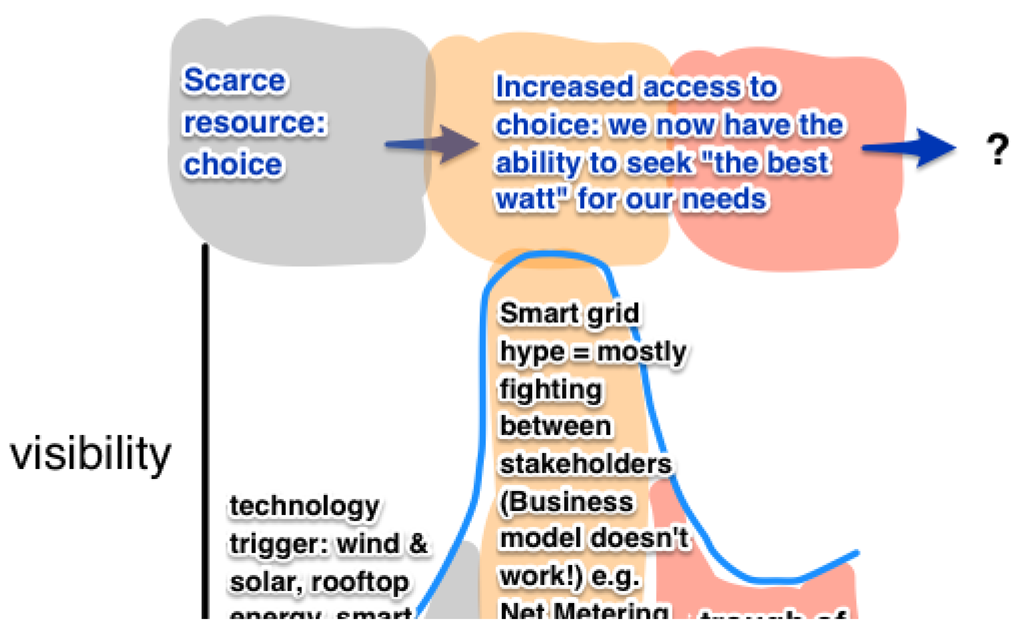
The bargain has been this: **in exchange for affordable dxdt, we accept a lack of choice for how we get our energy.** If you’re in San Francisco you only have one choice of electricity provider: Pacific Gas & Electric. The public utility commission grants them a sanctioned monopoly, in exchange for having a cap placed on what they’re allowed to charge you as a utility for providing you with dxdt. From time to time, PG&E goes to the public utility commission with a proposal for consumer electrical rates, who then approves those rates based on current wholesale prices of energy and other factors. In some deregulated regions, consumers can select among multiple providers of electricity, at least offering some choice, but upon making their selection still pay monotonously through a meter for a stream of commodity electrons. In essence, the regulated component of the rate we pay is not actually for the electricity itself (wholesale power prices are market rate and highly competitive) but rather for the dxdt component.

This bargain turned out to be highly productive. It put the right incentives in place to electrify our cities and towns, to build high-capacity, reliable mainframe plants and to make sure that the lights always turned on, cheaply. But what now? As the 21st century opens, we’re presented to a world of new possibilities but also urgent resource and climate related problems to address. Technology will certainly help determine what happens.

How can we make sense of what’s going on? Let’s turn to our idea of technology increasing access to scarce resources. With dxdt and choice as the scarce resources of the 20th century energy bargain, we can categorize energy technology breakthroughs in terms of access to these two entities.

In one corner, we have new technologies that increase our access to *choice* of which joule of energy we consume. Renewable energy like solar gives you one kind of choice: if the sun is shining, a solar panel owner can get momentary access to zero-emissions, zero-marginal cost energy. Same for wind. Consumer-sited energy is another: if you have a generator of some kind on-site, even a simple 3 hp Honda gas generator, you can *choose* to use that energy at your discretion. Rooftop PV systems and hot water heaters are other examples. Smart appliances and systems that can turn on and off intelligently in order to select the cheapest and best watts have arrived as well. And at a far more granular level, the imminent arrival of distributed IoT systems will empower formerly static components to become actors that make choices of their own — we'll come back to this later. The impact of all of this technology points in the same direction — away from the old grand bargain where you only had one option (the steady grid) towards a world where a consumer might have multiple options for how you source and consume your energy.

Our collective response? We're very excited about this increased access to choice, and we've heard a lot about how we need to build a "Smart Grid" to take advantage of these new options. There's just one problem: it's proved quite challenging to get anyone to agree on how this should work and who should pay for it. In the meantime, increased access to choice without improving our ability to shift energy in place and time (dxdt) leads to a lot of fights between stakeholders. What happens when the sun is shining but no one needs the energy? What about the opposite? Is Net Metering fair? If the traditional grid is the only network connecting the these distributed 'choosers', who is in control? **Without a corresponding increase in dxdt, increased access to choice leads to conflict and no clear business model.**

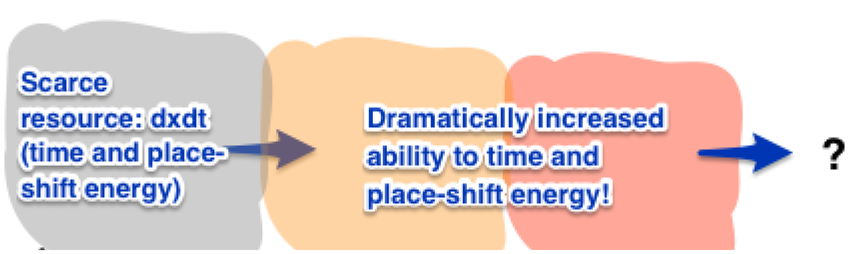


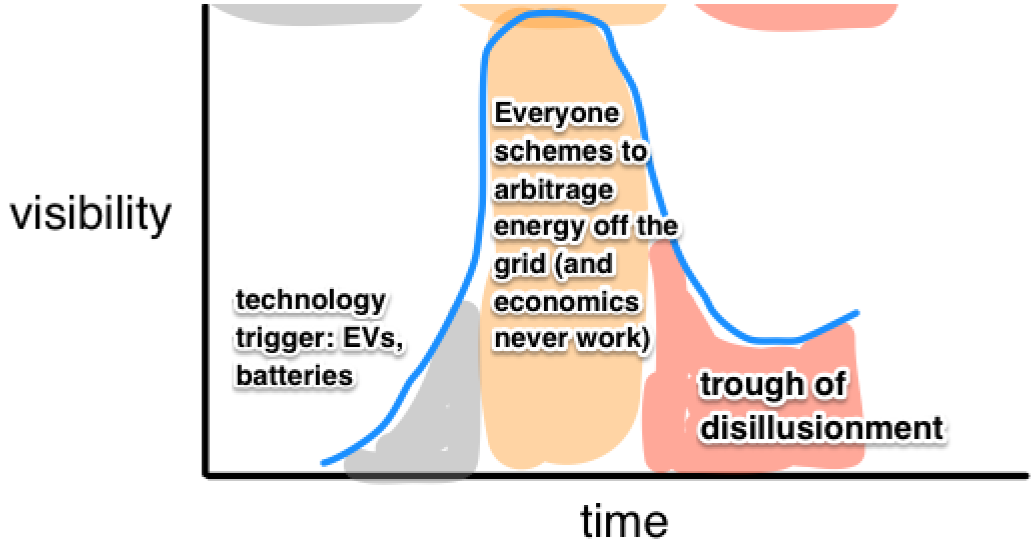
Meanwhile in the other corner, there’s another category of technology that’s increasing access to dxdt: energy storage and electric vehicles.

Energy storage is very clearly a form of dxdt. It lets you draw in energy at one time and consume it at another (and possibly a different place as well). If there is high supply or demand for energy at time A and low supply or demand at time B, energy storage lets you bridge that gap and resolve the difference. Electric cars go a step further: they quite literally are a battery on wheels that can charge up at at different locations, use that energy gradually as it drives, and even discharge its energy should the situation call for it. (Gasoline, which powers most vehicles on the road today, is also a highly effective form of dxdt. It’s dense, portable, and standardized.)

It’s worth repeating this point, because it’ll be important later: *electric vehicles are a form of dxdt, just like the grid*. One vehicle may not be able to store, move or consume very much energy — but a whole fleet of them develop a capacity and an agenda of their own.

In the meantime, a lot of people have gotten excited about energy storage — specifically, the prospect of arbitraging energy from the grid, buying at off-peak hours and selling at peak prices to make money. This sounds like a good gig, but it actually isn’t: the economics don’t work out. How come? Because without *choice* — without having many options from which we can get energy — it’s very hard to make money in arbitrage. We can choose to buy power from the grid at 3 am vs. 3 pm, but that’s pretty much it. **Without a corresponding increase in choice of where our energy comes from, increased dxdt is mostly underwhelming and yields no clearly profitable business model.**





But what about when we take a step back and see that both of these transformations are happening at the same time?

No one really knows what's going to happen. But I do believe we can say the following:

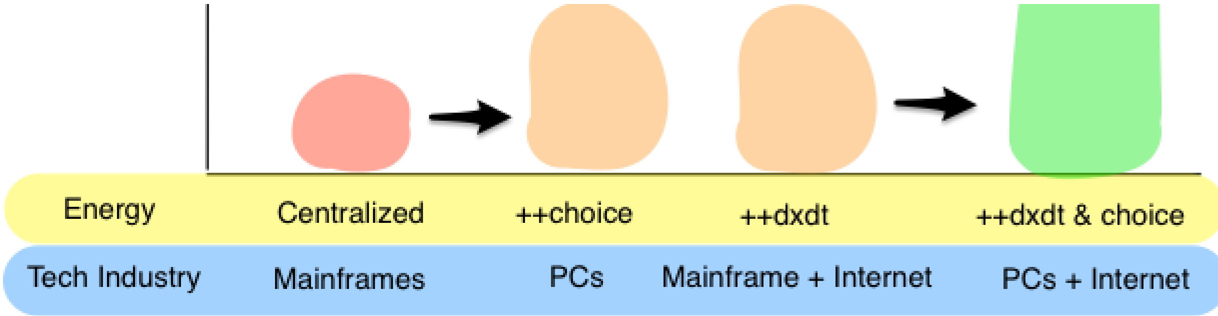
-The grand energy bargain in the 20th century is predicated on dxdt and choice as scarce resources around which the market is organized.

-Increasing access to choice of where, when and how we get our energy makes dxdt more necessary and valuable.

-Increasing access to dxdt, conversely, makes having access to different choices of energy at different times and places more valuable.

-Consumer sited energy, renewables, smart consumption, batteries, EVs and other kinds of technology are currently increasing access to both choice and dxdt, at the same time.

We are very close to a moment not unlike when early PCs and the early Internet, which initially evolved separately, finally found each other.



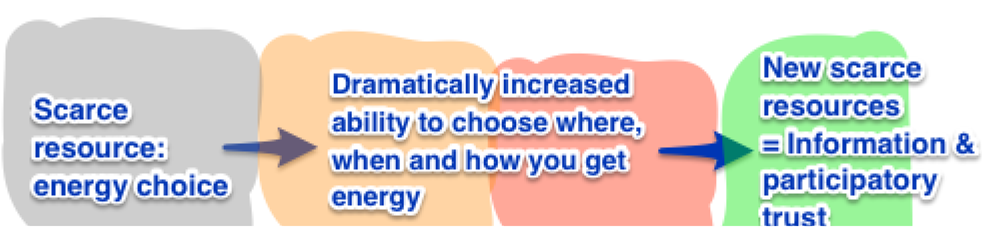
This should have two consequences in the near-ish future:

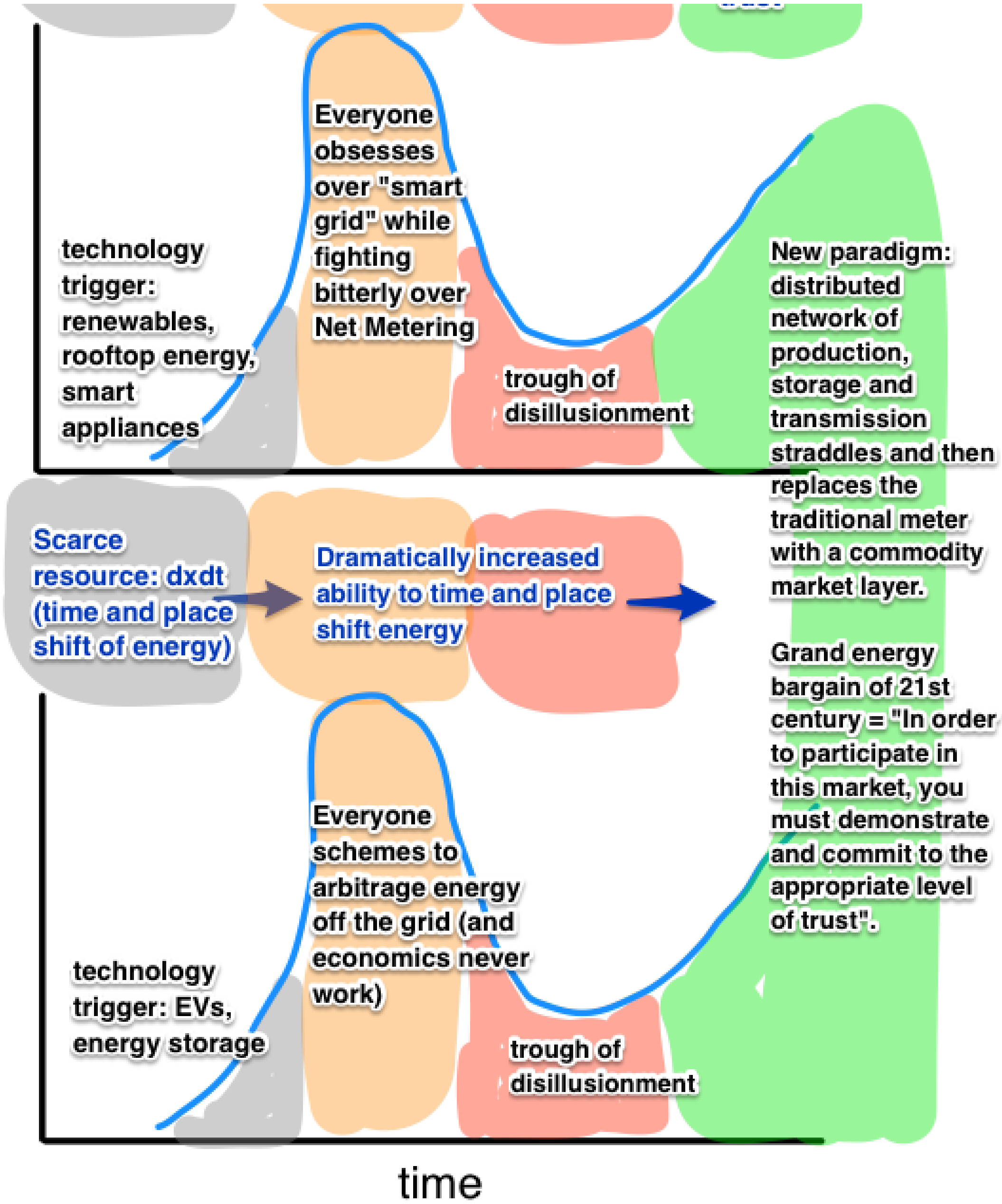
1. A virtuous cycle, not unlike Moore's Law, whereby more choice enables more dxdt and vice versa in a self-reinforcing loop.

2. Dxdt and energy choice will no longer be the central scarce resources of energy. Something new will take their place. Much as the grid turned power plants into fungible abstractions 100 years ago, so will happen to the existing grid in the next few decades.

What might this actually look like in real life? The combined Tesla + Solar City, or at least the idea behind the merger in principle, can help us out as a conceptual starting point. Solar City is a company that increases access to choice through their distributed, consumer-sited network of rooftop PV panels. Tesla, on the other hand, increases access to dxdt by deploying large numbers of electric vehicles, charging stations and Power Walls. I'm not saying Tesla + Solar City will surely emerge as winners, although we'll revist them later. What I mean here is the *idea* of Solar + EVs and its potential can best be understood as radically increased access to choice and dxdt, in tandem — and that's what makes it exciting. When we talk about Tesla / Solar City operating an "energy network" between its solar rooftops, cars and charging stations, this is what we're talking about.

Back to current reality — if access to choice is increasing, and access to dxdt is increasing, what does that mean? What will be scarce?



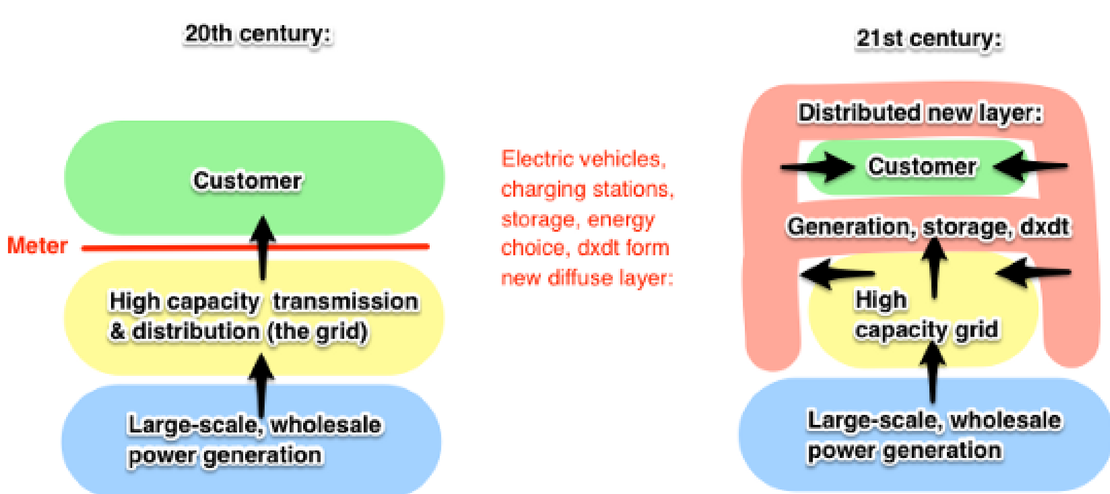


Here’s my best guess.

The physical electrical grid as we understand it will still exist, and will continue to be operated by the public utilities we’re familiar with. Most of our energy will still come from large, centralized sources — much of that from utility-scale natural gas, and eventually wind and solar. (Just as much of our computing today is still done in centralized locations. Mainframes persisted for a long time, and have since been superseded by giant server farms powering the cloud). There’s nothing “off-grid” about this — the plants and wires we know today will still very much exist. Surrounding this centralized backbone of energy production and transmission we will also have a highly distributed network of small-scale production, storage and transmission. This network will have many components: rooftop solar panels, batteries that can charge and discharge, electric vehicles, and their charging networks.

You can think of the relationship between the central trunk and the distributed peripheral branches as somewhat akin to that between Uber and a subway system. The subway system has a much greater absolute capacity along its trunk lines, and can move a very high volume very efficiently within those parameters. Surrounding this trunk, we have Uber — a highly diffuse, locally effective way to bring our electron passengers to and from the central lines, absorbing capacity variation, and even directly competing in situations where the economics permit. The majority of electrons will still take the subway for the majority of their journeys — but whoever can fulfill the many different kinds of "last miles" will probably have the more attractive income proposition.

The most significant change will be that this distributed network will effectively straddle and ultimately replace the Meter: the literal counter that calculates our energy payments, and also the dividing line between the two environments we currently call "In front of the meter" (utility-sited) and "Behind the meter" (consumer-sited). With the rise of consumer-cited generation and storage, particularly of the dispatchable kind (where utilities today can deploy and rely on these assets as if they were "Virtual power plants"), the line between what is in front versus behind the meter is poised to become very blurry- and ultimately disappear. So what replaces it?



The meter most likely gets replaced by an entirely new layer of energy where electricity can be stored, exchanged, and consumed. Almost like a distributed "Internet of energy" that is not controlled by any master coordinator but rather operates like a **distributed commodity market**. What will we find on this market? We'll be dealing in one very basic commodity: electrons. But there will be a number of different ways that they might be handled. We will probably see the creation of a few simple derivative contracts that replace the monolithic counting of the meter and pay out based on some possible underliers:

-The productivity of an energy-producing entity, such a solar panel, gas plant or nuclear plant

-The money paid out by an energy-consuming entity, such as a building or a car

-The money earned through arbitrage by an energy-storing entity, such as a battery or a car.

This commodity market type layer is fundamentally made possible, and in fact inevitable, by the distributed Internet of Things. Once these underliers become agents of their own (as they will), two very natural scarce resources should emerge: **information** and **trust**. Just as the grand energy bargain of the 20th century stated, "In exchange for access to dxdt, you agree to restricted choice", the grand energy bargain of the 21st century may state, "In order to participate in this ecosystem, you must demonstrate and commit to the required level of trust."

What does "the required level of trust" mean? Well, there are many different ways to participate in this market, each with their own requirements. If you're a homeowner and all you want is for your lights to turn on — in other words, for the market to act like the electric meter we're used to — then you need to provide a billing address, and maybe a credit history. If you're a dynamic circuit breaker that needs access to the information held by an adjacent load balancer, you need to demonstrate the appropriate digital credential to be granted read or write permission. If you as an entity want to trade on this market, and use information that you have to try to make money, then that requires some higher level of trust. If you want to be a major player on the market — say, operate a fleet of electric vehicles that are constantly buying, storing, selling and consuming energy — that too requires many different and ongoing exchanges of information and trust. In time, some kind of regulation or self-policing will emerge, although it’s hard to say what at this point.

Funny enough, if this comes to pass it will represent the final arrival of something we dreamed about in the 90s; one man in particular. That man was Jeff Skilling, and his dream was Enron. To be clear, let the record rightfully state that Enron deserves its final resting place in infamy. But nonetheless, you can’t help but think that Skilling was clearly ahead of his time. But the the lesson from history is clear: for this to actually work, it needs to be a distributed system like the Internet, and not a centralized model like Enron’s. I don’t think I need to explain why.

So how does this actually come about? As ideal an endpoint as it may seem, this seems like a pretty major change from the way things work today. Where are the most effective wedges going to come from? Who will hold the information? And who will hold the trust?

Well, let’s go back to part 3, where we talked about cars and other technological changes that increase access. Specifically, we talked about our ongoing shift from driver culture to car culture, the increased access to cars and drivers brought upon by the mobile phone (Uber), and the coming increased access to liquidity brought upon by autonomous vehicles and fleet programs. We asked the question, “What will cars want?” But we held off from commenting about the third major wave of change coming to vehicles — their electrification — because we were saving it for this post.

As it turns out, electric vehicles are going to be the perfect wedge into our new energy paradigm for the following reasons:

1. They are a form of distributed dxdt, as we’ve discussed.
2. The cost of producing and operating an electric vehicle (or a fleet of them) is heavily subsidized by its other function: transport.
3. They are going to be productive entities that can *want* things — and will probably get them.
4. They will be significant energy consumers themselves, granting them leverage as dxdt entities.

And so, we now finally have the right lens to look at what Elon Musk is planning for Tesla.

We already heard about Tesla Secret Master Plan Part 1: Use momentum from the Roadster to build the Model S, and then in turn the Model 3. Then we heard about Master Plan Part 2, which was largely about Tesla becoming a fleet manager of sorts (albeit with a bridge period where individual owners still own the cars). What’s going on in parallel, though, is quite a bit bigger in scope: Use cars as momentum to build Gigafactory production capacity and charging stations, and in turn *own the charging standard and therefore dxdt*. In the future, GM, Toyota or Apple could make the cars; Musk and Straubel mostly care about having them all have a Tesla-produced battery made in a Tesla Gigafactory running Tesla software and — most importantly — operate on the Tesla Charging Standard. That’s a real business.

Remember back when we asserted that the logical future scarce resources in the new layer of energy were Information and Trust? If Musk can seize the charging standard for EVs, he has deep hooks into both of these resources. He can use them as a powerful wedge into creating and owning the valuable parts of the new energy commodity market — where Solar City makes lovely sense as an integrated product offering, I must add. That’s why, just like in Chapter 3 where we mentioned about how one of the real battles beneath the surface for Uber was for maps, the real battle here for Tesla isn’t just for the cars. It’s also for the charging standard, the stations, and for deep hooks into the underlying actors in the Internet of Things that participate in the new distributed energy marketplace. Tesla doesn’t want to end up as the Compaq of this transition — they’d much rather be the Intel (battery architecture), the Microsoft (driving / on demand productivity network), or the Cisco (charging standard). Or even more than one.

One final point before we go. When we hear people talk about “The Smart Grid”, the massive and broadly supported Public-Private initiative to coordinate all of this distributed activity, what is that going to be? I’ll get in trouble for saying this, but when you hear “Smart Grid”, think *Sun Microsystems*. Hearing “Electric cars, solar rooftops, and dynamic pricing will all run on the Smart Grid” sounds an awful lot like the old tagline, “The Internet runs on Sun Microsystems.” Here’s the thing: that’s not wrong. The backbone and interconnecting glue of the Internet *did* run overwhelmingly on Sun’s SPARC architecture. (And still does, in a few places.) Sun was instrumental in making the Internet *work*. But in the long run, they did not win: they were caught between paradigms, not quite the old and not quite the new. If a mammoth, centralized Smart Grid is our Sun Microsystems, then the distributed energy layer I believe will emerge might initially look like Red Hat Linux. For anyone looking for the next layer, that’s where I’d start my search.

In summary, all I can say is this: it’s going to be wild. We’re very close to our “PC, meet the Internet” moment for energy. When PCs came online, the world changed forever — and so it may be with our next layer of distributed energy. So many things are coming together: cheap renewable energy driven by the falling costs of solar and wind, an onset of highly subsidized energy storage inside of cars, the changing nature of the ownership of cars itself, and the emerging IoT glue that’s going to bind it all together. No one knows what’s going to happen. And we can’t wait.

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Thanks to Nikhil Krishnan.

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