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26. Chasing locomotives

In which locomotives remind us that technologies compete, that fuels seldom do, and that technologies habitually evolve from inside-out to inside-in.

Jammed within a few decades surrounding the mid-20th century, diesel locomotives competed with steam locomotives for the honor of pulling trains. Diesel locomotives won. This was a competition between service technologies, diesel locomotives against steam locomotives. It was not a competition between fuels, not a competition between coal and oil. Yet the victor in the locomotive contest determined the victor in the fuel contest. Coal lost. Oil won.

We like to believe that things like price and availability determine the outcome of economic competition—especially competition among commodities. But neither price nor supply determined whether coal or oil would pull trains. Instead, the coal versus oil competition slipstreamed behind the locomotive competition. The coal versus oil contest was determined on a locomotive playing field, using locomotive competition rules. Fuels merely watched the action from the bleachers—rapt *aficionados*, critically interested in the outcome, but glued to their seats, unable to participate in a game determining their future.

Technologies compete. Fuels watch.[1]

The 20th century also launched the electricity age, an age distinguished by the profound cultural impact of electric technologies. Swelling electricity production differentiates the 20th from previous centuries. But electricity production was merely the response from the bleachers. Down on the playing field, the real action was competition among service technologies.

During the early decades of the century, service technologies powered by electricity competed with those that weren't—electric streetcars displaced horse-drawn streetcars, electric lightbulbs beat out coal oil lamps. Then, about mid-20th century the nature of the competition changed. More and more, often *all*, competitors were powered by electricity. Subways challenged streetcars for urban transportation; fluorescent lights fought with incandescent lightbulbs for illumination and, in the century's final years, e-mail began knocking out fax for quick communication.

Déjà vu is an overused, oft-misused, phrase popularized by Yogi Berra when he added his famous redundancy "all over again". But sometimes it's exactly the right phrase. For, just as the 20th century launched the electricity age, the 21st century will launch the hydrogen age. And while details of the hydrogen launch are unpredictable, the patterns of 21st century energy transitions will be classic *déjà vu*.

Repeating patterns of the 20th century, during the 21st century our energy system will be shaped by competitions among service technologies rather than between fuels. During the first decades, competition will be between technologies that are hydrogen-fuelled and those that aren't. Then as the century proceeds, winners and losers will be selected from among competitors *all of whom* use hydrogen—spiced, sometimes, by electrical technologies entering the fray.

Let's stay with our locomotive example. Early in the 21st century, probably after a preliminary bout between fuelcell and diesel buses, we can expect fuelcell locomotives to compete with diesel locomotives for the right to pull North American trains.[2] Once again, this will be a head-to-head competition between technologies, not a competition between oil and hydrogen. Sooner or later diesel locomotives will lose. Fuelcell locomotives will win. The commuter-sheds of great cities will likely host the first skirmishes. Stay tuned.

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[1] For a brief time just before steam was eclipsed by diesel, some steam locomotives were oil-fired—often bunker-C. But soon diesel locomotives fully eclipsed steam locomotives, whether fired by wood, coal or oil. And that reinforces the fact that, overwhelmingly, technologies compete rather than fuels. A steam engine is an *external* combustion process, so anything that can be burned externally can energize a steam engine. A diesel engine is an *internal* combustion process, so the technology is very fussy about the fuel it consumes. Because the fuel fed to diesel engines is so engine-specific, the fuel itself came to be called "diesel". Diesel fuel was designed for the technology, not the other way round.

[2] I've said North American, although to greater or lesser degrees the competitions will be global. In Europe, with much higher population densities and higher train frequencies, many trunk lines have been economically "electrified". In contrast, except for parts of the US eastern seaboard, the longer distances and lower train frequency that characterize most North American railways have precluded the capital cost of direct "electrification". Therefore, North America is the most likely venue for early-adopter fuelcell locomotives.

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Dad started our family's 1947 black Plymouth. Following a brief squabble between my brother and me over who would get the front seat, we all piled in. Mother joined us too—in the back seat for this adventure (front seat for church). She always enjoyed family adventures, but for this adventure her purpose was to inject a measure of responsibility because we were off to chase locomotives.

At the time we lived in Belleville, a southern Ontario town on the shores of the Bay of Quinte—a meandering, bucolic bay on the north shore of Lake Ontario. The Canadian National Railway line passes through the north side of Belleville—a town about a third of the way from Toronto to Montréal. The Toronto–Montréal run was too long for steam locomotives to complete without taking on coal and water. So in the late 1940s, watering and coaling was done about a mile east of the Belleville station. Locomotives needed water more frequently than coal, so "water spouts" were located more frequently along the line than "coal chutes". At Belleville, the locomotives got both.

Eastbound trains pulled slowly out from the station to halt when the locomotives were "spotted" under the spouts. Then, coaled and watered, the great locomotives began their run for Montréal. Like monstrous black bulls angrily pawing dirt before charging, these giants from the Coal and Iron Age would, intermittently, lose traction to spin their enormous driving wheels on the track. Synchronous with each driver revolution, staccato jabs of steam escaping the cylinders[3] and geysers of smoke bursting from the stack startled the countryside, especially when the frequency jumped as the drivers lost traction to skitter-spin above the track. Gradually the train gathered speed for Montréal. It was grand. And bait for the Plymouth.

A road runs east from Belleville along the north side of the railway. Rail grades must be gradual. But in those days, country roads followed the rolling landscape.

The race is on. Yet it isn't really a race. Rather it is one dad showing his sons the majesty of those proud steam locomotives—and how they worked. We start slowly. Seems the train would never reach speeds to challenge the Plymouth. Five miles per hour, then ten. The road climbs above the locomotive and we look down smugly. Bonded by mutual awareness the engineer waves from his cab. Train and car gather speed in tandem. Now the road drops beneath the tracks and we look up to the locomotive's underbelly, the counterweights on the driver wheels turning faster and faster. Now the road is at track level, jets of steam and smoke jabbing at higher and higher frequencies. The Plymouth's speedometer touches fifty...sixty-five[4] ...flashing silver-painted connecting rods rush up and down, back and forth, faster and faster, united with the stack's sharp ejaculations. We are witnessing perhaps the most enthralling sight of the steam era—right at that era's apogee. Finally, mother suggests, "I think that's fast enough Gilbert". Sadly, Dad gives up the chase, as the irrepressible train effortlessly slips ahead of the Plymouth, gradually at first, then faster and faster until it disappears round a bend seeking Montréal.

When chasing locomotives we kids were enveloped by the grandness of this Coal and Iron Age technology, at its very peak—just before it slipped away into history. We could see, right in front of us, how those lovely locomotives *worked*. We saw the drivers, the connecting rods joining the drivers to the pistons, and the counterweights on the drivers that balanced the connecting rods so the locomotive wouldn't hop down the track with each driver revolution. Today I realize the connecting rods were also building links between a dad and his sons. Wish I could talk to him now.

Today there may be other dads taking their kids to watch locomotives pull out of Belleville. But I doubt it. Not because today's parents don't want to show their kids interesting things—nor because TV traps kids indoors. Rather, I suspect it has something to do with the fact that steam locomotives were designed inside-out and today's diesel locomotives are designed inside-in. You cannot see the important workings of a diesel locomotive as you watch it pull out from a station. Their important bits are hidden behind their skin. But the workings of steam locomotives were "in your face".

I better say something about my choice of "inside-in" to distinguish from "inside-out". I intend it to mean *like us*. Most of our workings—liver, heart, lungs, brain—are inside, invisible to a passerby, hidden by a covering we call our skin. Indeed, most living things—cats and dogs, whales and sharks—are designed with most of their important bits and pieces on the inside.[5] When I began to write this article I first used "rightside-out" to distinguish from inside-out. But then I realized this choice might suggest bias, might imply "correct" side. So I tested other phrases, like "outside-out" or "skin-side-out" or "smooth-side-out". "Skin-side-out" made me queasy. Don't know why. But couldn't use it. And the problem with "outside-out" was that some might say, "the 'outside' *is* 'out' so *everything* is 'outside out'". Finally, not all outsides are *smooth*. So in the end I chose "inside-in".

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[3] In later years, I learned that most of the cylinder's exhaust steam was directed through a nozzle in the smoke-box up the stack, thereby providing forced draft for the firebox.

[4] In the 1940s and 1950s, Canada had not yet followed the world by adopting the much more practical metric system. But as we entered the 21st century, there was only one great nation still doggedly holding to its non-metric past.

[5] Our skin does a lot of work too. But I'm sure we all agree that *most* of our workings are inside. Of course, like any system, we can debate which bits and pieces may be more important, but still acknowledge that if any are missing, the system will die. Interconnectedness is a theme that runs through these energy system articles.

Evolution from inside-out to inside-in is a pattern that seems to characterize how technologies mature. Ships once propelled by oars and sails came to be pushed by steam turbines, then diesel engines and, sometimes, nuclear power plants. Merchants who once weighed rice and mangos with balancing sticks—the Chinese called them *chung*—now use electronic scales. Hydraulic power, originally harvested by splashing water wheels is today harvested by humming turbines buried within concrete generating stations. Yesterday, when farmers wanted to improve their produce they would sometimes graft the branches of one plant onto the trunk of another. Now we implant genes.

Inside-out to inside-in evolution is one aspect of a more general trend for technologies to mature from transparency to opaqueness. Therein lie the seeds of misfortune. Because opaqueness often builds mistrust and fertilizes technophobia. The more opaque, the more mistrust blooms. Most often, this mistrust runs counter to the reality that inside-in designs are usually better designs. So our mistrust is often aimed at those technologies that can most improve our lives—and the health of our planet. (As we being the 21st century, a good example is the widespread mistrust of genetically modified foods—a mistrust enhanced by the technology's opaqueness to public understanding, exacerbated by fear of unintended consequences.)

Steam locomotives were characterized by low efficiencies, soot-coated downtowns and poor service. Having to stop once for coal and several times for water during a 300-mile run is but one symptom of poor service.[6] Diesel locomotives, the first step towards inside-in designs, are more efficient, cause less environmental damage and provide better service.

In the coming decades, when railroads move from diesel to fuelcell locomotives they'll be even more inside-in, more opaque to understanding. Yet because they will intrude much less on the environment, operate at greater efficiencies and provide better services, fuelcell locomotives will be *better*.

Of course we can never claim *all* inside-in technologies are better than the inside-out technologies they displace. (I enjoy recreational sailing, preferring the inside-out sails of my sailboat, *Starkindred*, to the inside-in engines of a powerboat. In part, my preference comes from *seeing*, moment by moment, what's making *Starkindred* move—visualizing the wind flowing over the sails providing lift—watching the behavior of small strings of wool attached to the sails to know whether the air flow is laminar or turbulent.) Nevertheless, it's sobering to remember that living things are nearly always designed inside-in. Nature has her reasons.

Our coming hydrogen age holds extraordinary promise. Yet there could be a dark cloud creeping up to shade the bright sky of promise. That dark cloud is technological mistrust fertilized by the unstoppable trend towards evermore inside-in technologies—like fuelcells and electrolysers.

The difficulty we all have in understanding the workings of opaque technologies may also be the catalyst driving today's renaissance of irrationality. More people seem to be turning from rationality, substituting a kind of narcissistic spiritualism that allows them to wallow in the joy of strongly held opinion unencumbered by critical thought. Worse, even for things that *do* have straightforward rational explanations, like the loss of a Mars probe, some folks enjoy conjuring spooky causes like a great Martian mind intent on destroying emissaries from Earth. It's scary: this bloom of irrationality and technophobia following a century so techno-enriched.

Soon today's nascent hydrogen age will enter its launch phase. Locomotives have given us some of the patterns:

- The future will be determined much more by competition between *service* technologies than between fuels.
- Initially, the competition will be between hydrogen-fuelled and (what we now call) conventional-fuelled technologies.
- Later, most competition will be between technologies all of which are hydrogen-fuelled.
- Fuelcells and electrolysers—central technologies of the hydrogen age—will more closely mimic nature than the technologies they replace—yet their inside-in designs may bring a new wave of public mistrust.

We must get started. And in starting, we should anticipate the cultural stumbling blocks we'll find along the way. Many, perhaps most of these stumbling blocks will be cultural, especially our usual fears of change, bolstered by necessarily opaque technologies.

Today, many people argue for a foundation of ethics when we select from among the plethora of technology-allowed choices. I agree. My difficulty is to be confident about what is ethical.

It might be easier to have confidence in what is unethical. I consider it unethical to plead, with volume and shrillness, for, or against, one or other technological pathway *without* having paid the entry fee of critical thought. Critical thought does *not* require that we be specialists, just that we make a reasonable effort to inquire, learn and think. Even then, in the fullness of time, sometimes we might be wrong. But we should make the effort.

[6] During the mid-20th century, small hamlets were often dismissively called "jerk water" towns. The term was born when locomotives didn't stop for watering. Rather, they took on water by "jerking" it from water troughs laid down between the rails—as they ran, at speed, through small "jerk water" towns.

Over the next series of articles, we'll look at many of the patterns and issues we will encounter as we enter the hydrogen age—which I sometimes call the "hydricity" age because it will, forever, intertwine *both* hydrogen and electricity. With luck, the next articles will help us better understand the choices and wonderful opportunities we'll have as we launch hydricity.

Theses choices must be both informed and often courageous. Because how we choose will not simply shape the 21st century; it will also determine whether or not civilization survives.

This is the twenty-sixth in a series of articles by

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