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## **Adaptive Risk Management: Powered by Network Science**

By Alan Laubsch

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# Adaptive Risk Management: Powered by Network Science

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## Abstract

Adaptive risk management harnesses social intelligence to identify emerging risks.

We have entered an *age of disruption* where exponential technologies are transforming every industry. The ability to pivot in a rapidly evolving ecosystem is essential. Centralized “predict and control” paradigms will increasingly fail as complex interactions drive phase transitions. Successful organizations will harness *social intelligence* to “sense and respond” to giant waves of change.

Maps amplify intelligence to help us navigate challenging terrain. Maps play a central role in all command centers, enabling rapid risk identification with a shared visual language. Interactive *financial network maps* allow analysts to explore and diagnose systemic fragilities and mitigate critical vulnerabilities. Dynamic financial maps can also build visual intuition to detect escalating risk patterns. After observing early warning signals, analysts can apply network analytics to estimate likely second-order effects. This allows organizations to proactively manage emerging risk before tipping points are crossed.

Furthermore, to manage global systemic risks, we must find ways to cooperate across boundaries. Systemic risk maps can serve as mass collaboration platforms to spark network intelligence and coordinate effective joint actions.

Key words: financial cartography, financial networks, network intelligence, emerging systemic risk, early warning, stress testing, value at risk (VaR), outliers, black swan, dragon king.

# 1. Introduction: Financial Network Science

Network science is an interdisciplinary field that has transformed the way we see our world, from biological to technological networks. Network algorithms help us see hidden patterns in complex data. For example, Google's PageRank algorithm allows us to find critical information on the Internet. Network algorithms enable early detection of systemic risk, which includes degenerative diseases, cyber attacks and financial contagion. Financial Network Analytics (FNA) builds intuitive visual maps of financial networks to help risk managers identify and manage systemic risks.

Financial network science was pioneered by academics in the 1990s. Innovations include minimum spanning tree (MST) maps (Mantegna 1999) for intuitive visualization of correlation networks. The first map of a major financial system was the FedWire interbank system (Soramaki et al. 2006), which revealed a core-periphery structure. As the global financial crisis revealed the dangers of opaque networks, regulators have dedicated more resources to mapping of interbank networks (with some jurisdictions even monitoring daily interbank liquidity and credit exposure). Interactive network visualizations for economic, market, credit and liquidity risk have also been implemented by leading financial infrastructures, banks, insurers and asset managers.

## 2. Adaptive Risk Management Framework

The core principle behind *adaptive risk management* is to broadly harnesses social intelligence to identify emerging risks. We consider two interdependent perspectives:

- 1) **Macro**: We seek to uncover **hidden** structural risk (e.g., fault lines) and source credible stress scenarios from thought leaders. Each scenario is tagged with key early warning indicators.
- 2) **Micro**: We monitor **visible** risk in the form of market-based early warning signals, focusing especially on risk outliers that indicate potential regime shifts and point to key stress scenarios.

Macro and micro perspectives inform each other in a continuous feedback cycle. For example, we might observe unusual movements in a specific asset (micro) that leads us to evolve a new macro risk scenario. A case study of how unusual movements in energy shares in 2014 led us to identify a major disruptive investment theme is found below.

This general framework is described in greater detail in Laubsch (2014).

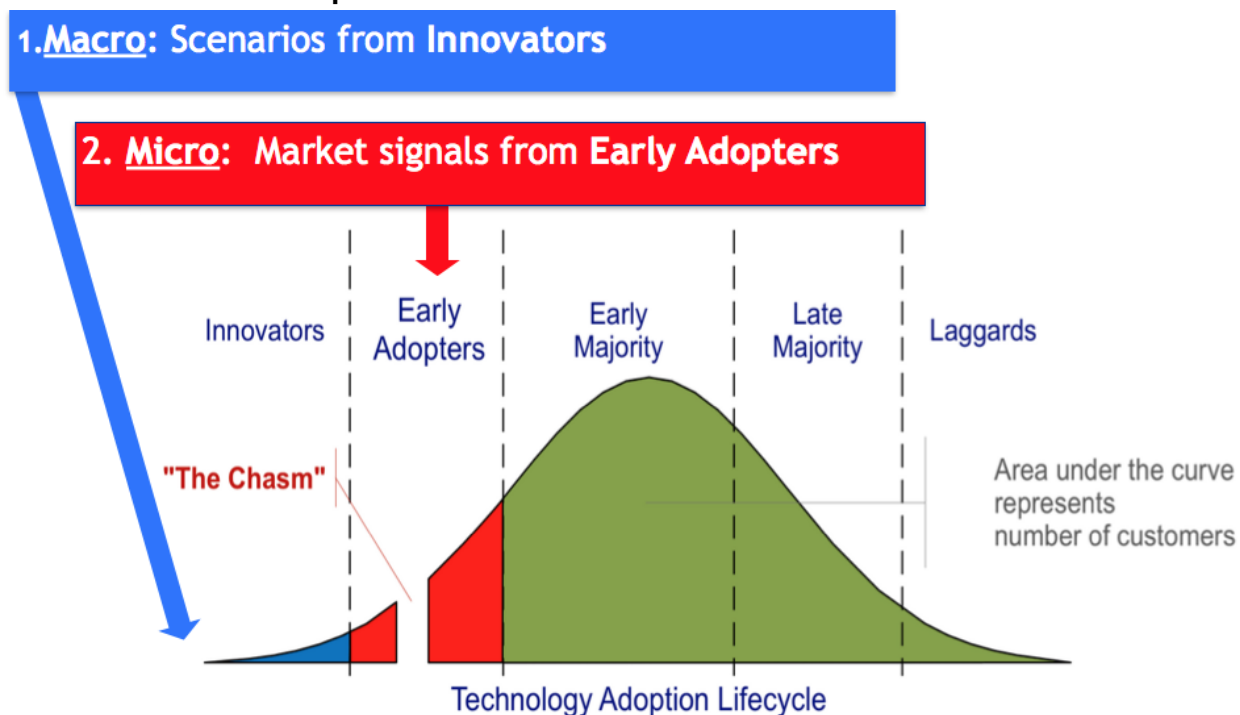
## 3. Social Diffusion of Disruptive Innovation

*Disruptive innovation* does not diffuse gradually. There is often an extended period of stasis until environmental conditions are right. A wave of *early adopters* then precipitates a *tipping point* of

broad adoption. Geoffrey Moore's seminal *Crossing the Chasm* (1999) describes this sociological *technology adoption lifecycle*.

Disruptive investment themes emerge similarly. *Innovators* propose credible hidden risks (many of which may never emerge). Early adopters hone in on escalating visible risks, and amplify early warning signals, which are eventually seen by the *early and late majority*. Intelligence is not evenly distributed, and the most credible risk signals emerge from the leading edge: Innovators reveal potential risks and early adopters sense emerging risks. Fig. 1 shows how we have integrated macro and micro perspectives with the technology adoption lifecycle social diffusion process.

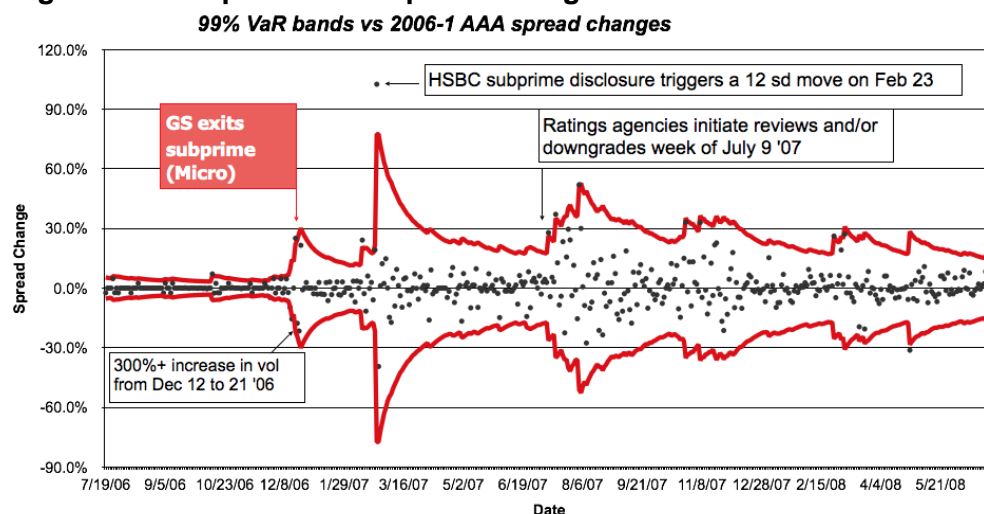
**Fig. 1. Social diffusion of disruptive innovation**



Graph adapted from Wikipedia: <https://commons.wikimedia.org/wiki/File:Technology-Adoption-Lifecycle.png>

The U.S. subprime crisis illustrates this social diffusion process. Innovators like Robert Shiller and Nouriel Roubini warned about a U.S. housing bubble since 2005, but it was not until the following year that early adopters traded on this disruptive theme. Goldman Sachs famously decided to exit the U.S. subprime markets after observing unusual value-at-risk (VaR) outliers in December 2006 (Laubsch 2008). Fig. 2 shows the “earthquake” spike in AAA subprime bond spread volatility that spurred Goldman’s exit (well before HSBC became the first bank to announce subprime losses on Feb. 23, 2008).

**Fig. 2. U.S. subprime bond spread changes vs. 99% VaR bands**



## 4. Outliers as Early Warning Signals

Outliers signal a potential regime shift as early adopters trade on emerging themes, and, yet, many outliers are simply noise. The challenge is to hone in on signal over noise. Network science allows us to evaluate outliers in context of the overall financial network. Are outliers confined to one asset class, or are they spreading to related assets? Are outliers clustering or amplifying over time?

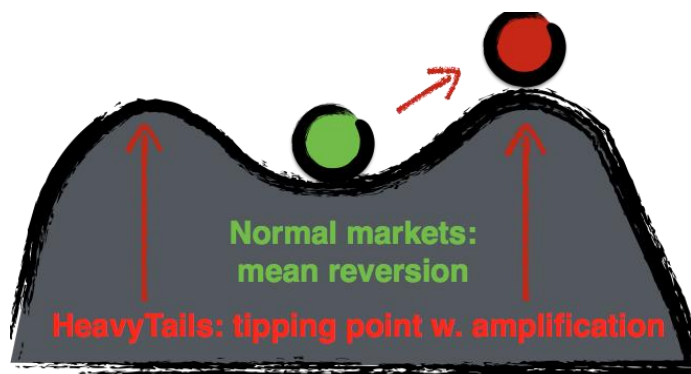
We will use the 2014–15 global energy meltdown as a case study to show how network visualization helped us identify an emerging systemic risk that continues to escalate.

## 5. Energy's Dragon King

On Jan. 9, 2007, Steve Jobs announced the iPhone. It was famously dismissed as a "niche product" by Nokia's then CEO. But as we all know now, it heralded a disruptive event for the mobile telecom sector. June 24, 2014, was such a day for global energy markets. It marked the emergence of a disruptive investment theme that saw investor appetite for fossil fuels spiral like Nokia's mobile marketshare. Yet its magnitude was not widely recognized at the time.

Far from being an unpredictable *black swan* (Taleb 2007), the global energy meltdown was a classic *dragon king* (Sornette 2009): structural risk that amplifies after a precipitating event, as Fig. 3 shows.

**Fig. 3. Landscape of structural risk illustration**



For energy shares (XLE), this tipping point occurred in June 2014. It was a classic case of emerging risk surprising a complacent market: Global indices were at record levels with low volatility. Low volatility implies low visible risk, and that our attention should therefore be on uncovering potential hidden risks. XLE was the second best performing sector in the Standard & Poor's 500 index. But an increasing number of prescient investors saw that energy was at the edge of a precipice and sold even as XLE kept reaching new highs.<sup>1</sup>

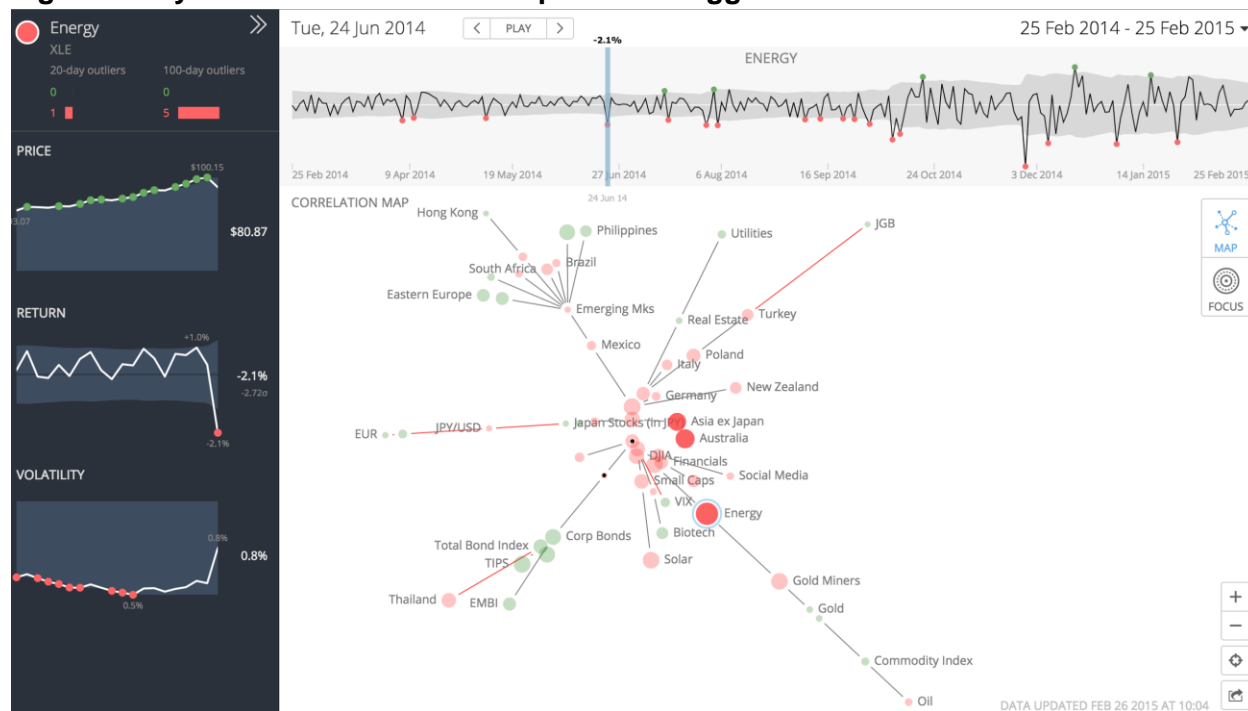
Fig. 4 shows a minimum spanning tree (MST) correlation map<sup>2</sup> of about 50 of the most liquid global ETFs on June 24, 2014, generated using FNA's HeavyTails correlation analytics. Nodes represent ETFs, and exceptional negative returns are deep red. Closely correlated assets have short links, and negative correlations are shown as red links. The tree is radially oriented, and assets at the center are the most connected to other nodes and therefore the most systemically important. Energy is highlighted as the biggest VaR outlier,<sup>3</sup> plunging by 2.1 percent on a day the S&P 500 only lost 0.6 percent. This was especially surprising because there was no significant energy-related news. Oil was close to peak levels and would only start its downward slide in July and fall below \$100 in August. Bloomberg *Money Clip* mentioned energy's surprising fall without explanation, and then proceeded to recommend a list of "cheap" energy shares (they would get much cheaper). At JPMorgan & Chase, we would organize meetings to discuss significant VaR excessions. This was exactly the kind of situation we would be most concerned about: a major excession that we could not readily explain. Someone acted on risks that were effectively invisible to the rest of us.

<sup>1</sup> We saw this from a 5 to 0 imbalance in upside vs. downside VaR outliers.

<sup>2</sup> MST translates a correlation matrix into an undirected graph to show the strongest correlations.

<sup>3</sup> We use standard RiskMetrics' exponentially weighted moving average (EWMA) with .94 decay to calculate VaR.

**Fig. 4. HeavyTails MST correlation map: XLE as biggest outlier**

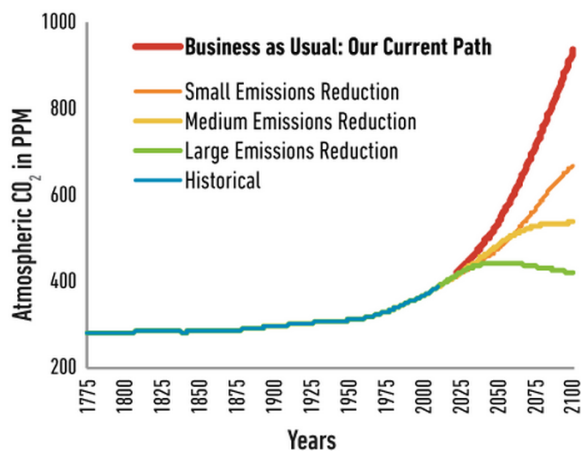


## 6. Energy’s “Canary in the Coalmine”

Fossil fuels face the “perfect storm.” Media has mostly focused on the big short-term drivers: global growth and competition (e.g., Saudi vs. shale). None connected the June 24 Risky Business Project announcement about the economic risks of climate change<sup>4</sup> as a candidate for precipitating the energy selloff. Their extensive climate risk research report was signed by nonpartisan financial leaders and advocates large carbon dioxide curbs to mitigate potentially catastrophic risks (see Fig. 5).

<sup>4</sup> Risky Business Project, “Risky Business Report Finds That U.S. Regions and Business Sectors Face Significant Economic Risks From Climate Change,” press release, June 24, 2014, <http://riskybusiness.org/blog/risky-business-report-press-release>.

**Fig. 5. Atmospheric CO<sub>2</sub> scenarios**



Source: Riskybusiness.org

The report quotes ex-Treasury Secretary and Risky Business Project co-chair Henry Paulson:

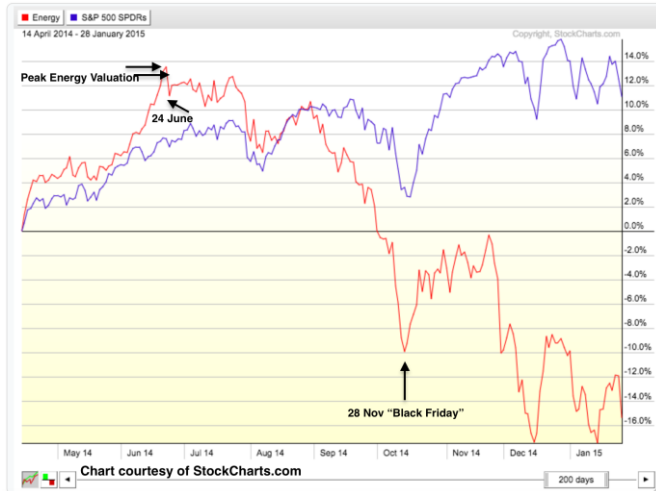
I know a lot about financial risks—in fact, I spent nearly my whole career managing risks and dealing with financial crisis. Today I see another type of crisis looming: a climate crisis. And while not financial in nature, it threatens our economy just the same.<sup>5</sup>

The implications of the recommended *large emissions reduction* scenario would be severe for energy firms. Given that no other news warranted such a steep drop in energy shares on June 24, we conclude that this announcement was the most likely precipitating event. Fig 6. shows XLE's phase transition from second best to worst sector in the S&P 500.

<sup>5</sup> Risky Business Project, "Risky Business: The Economic Risks of Climate Change in the United States," report, June 2014, [http://riskybusiness.org/uploads/files/RiskyBusiness\\_Report\\_WEB\\_09\\_08\\_14.pdf](http://riskybusiness.org/uploads/files/RiskyBusiness_Report_WEB_09_08_14.pdf).



**Fig. 6. Energy (XLE) vs. S&P 500 (SPY) performance**



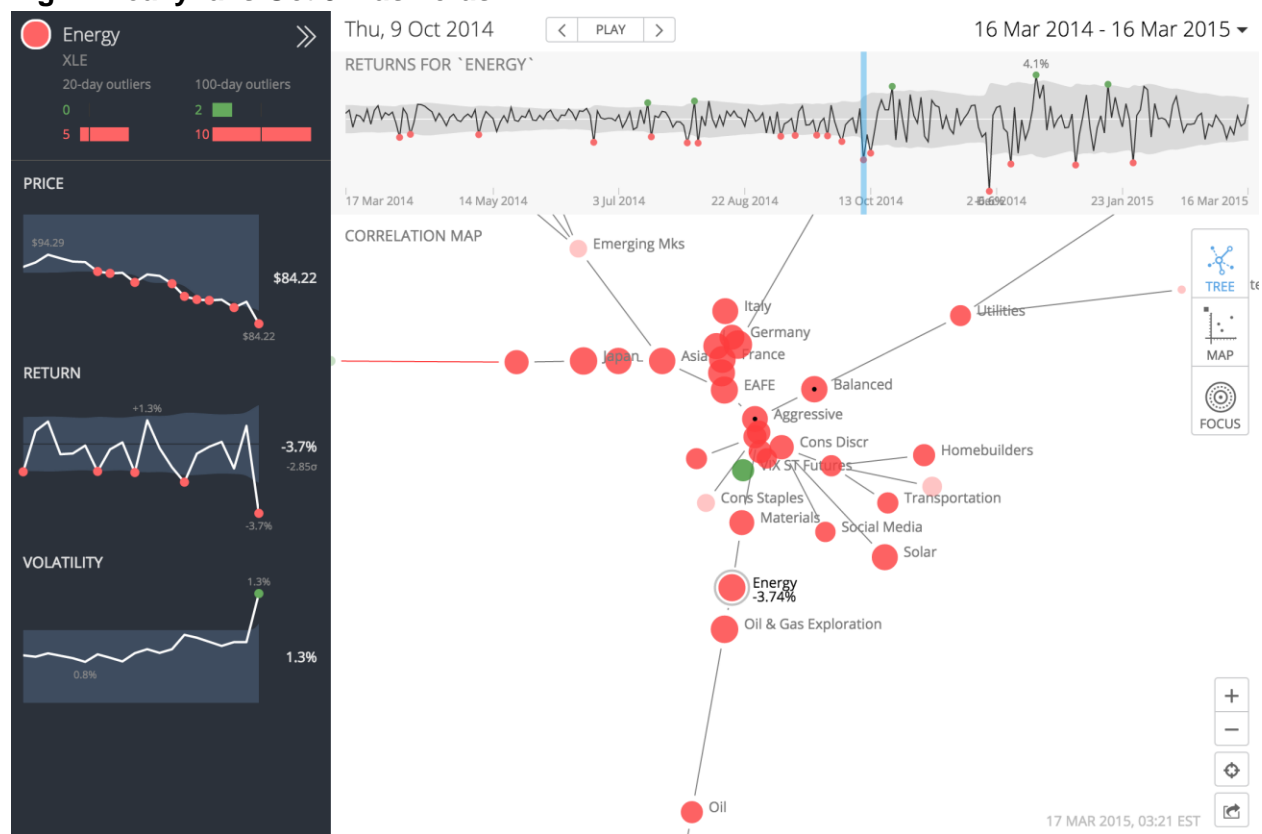
## 7. Systemic Risk Escalates Until October Flash Crash

Systemic risk increased from August to October 2014 as weakening global growth pressured commodities and geopolitical tensions flared with Russia. Outliers and volatility escalated for risky assets until the October “flash crash” saw the S&P 500 lose over 7 percent. Fig. 7 shows a snapshot of the Oct. 9 crescendo where XLE was the top outlier with an exceptional  $2.85\sigma$  (standard deviation) plunge.<sup>6</sup> Red flags would have been raised by September at active trading institutions after engaging weekly as opposed to monthly energy VaR outlier discussions:<sup>7</sup> XLE was already on its fourth negative outlier in 20 days by Sept. 25 when the S&P 500 saw its first.

<sup>6</sup> Note also that correlation networks “collapse” under stress, so we have zoomed in to focus energy.

<sup>7</sup> A 95 percent daily confidence VaR implies exceptions one-out-of-20 trading days on average.

**Fig. 7. HeavyTails Oct 9. flash crash**



## 8. Disrupting Fossil Fuels

Even as broad markets staged a V-shaped recovery, energy shares remained volatile and underperformed. This made sense to those who recognized the structural shift in markets. With a tipping point in awareness about the risks of climate change and the need for large emissions cuts, investors are increasingly pricing carbon risks. Fossil fuels face a tsunami of three disruptive investment themes:

- 1) **Divestment** (e.g., Stanford University Endowment, Rockefeller Brothers Fund);
- 2) **Renewables** (e.g., exponential drop in solar cost plus battery innovation); and
- 3) **Stranded assets** (due to inevitable carbon pricing or limits).

The Sept. 22, 2014, fossil fuel divestment announcement by Stephen Heintz, president of the Rockefeller Brothers Fund, ahead of September U.N. Summit on Climate Change is telling:

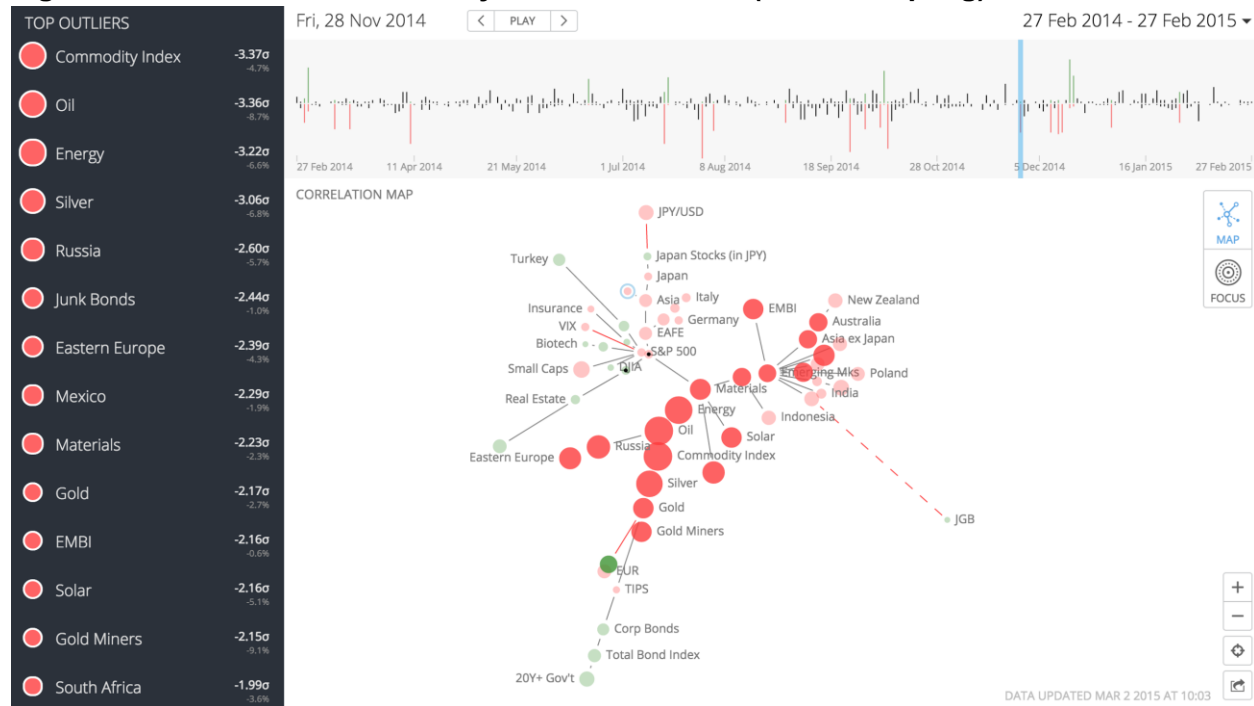
John D. Rockefeller, the founder of Standard Oil, moved America out of whale oil and into petroleum. We are quite convinced that if he were alive today, as an

astute businessman looking out to the future, he would be moving out of fossil fuels and investing in clean, renewable energy.<sup>8</sup>

## 9. “Black Friday” OPEC Surprise

We now see there’s more to the global energy sector’s decline than a temporary oil oversupply. The April 2014 *Institutional Investor* cover story discusses climate change and divestment, and hedge fund manager Christopher Hohn gets to the crux: “If you believe over time a carbon tax is coming—which I do—and if you believe in climate change, 80 percent of the reserves of energy companies can never be extracted.”<sup>9</sup> Saudi Arabia’s “Black Friday” decision not to cut production should therefore not have been a surprise. Seeing the inevitability of carbon limits, producers will pump at maximum output while they still can. Fig. 8 highlights oil-sensitive assets that were most impacted by OPEC’s production decision. In this fascinating episode, we saw a dramatic decoupling of broad markets with energy sensitive assets: The Dow Jones industrial average was up 0.05 percent and S&P 500 slid 0.2 percent as XLE crashed by 6.6 percent (3.22σ).

**Fig. 8. Nov. 28, 2014, “Black Friday” oil driven selloff (and decoupling)**



<sup>8</sup> See Suzanne Goldenberg, “Heirs to Rockefeller Oil Fortune Divest From Fossil Fuels Over Climate Change,” *The Guardian*, Sept. 22, 2014, <http://www.theguardian.com/environment/2014/sep/22/rockefeller-heirs-divest-fossil-fuels-climate-change>.

<sup>9</sup> Michael Peltz, “Climate Change and the Years of Investing Dangerously,” *Institutional Investor*, April 7, 2014, <http://www.institutionalinvestor.com/Article/3327752/Investors-Endowments-and-Foundations/Climate-Change-and-the-Years-of-Investing-Dangerously.html?ArticleId=3327752&single=true#.U1gReFVdWbM>.

## 10. Disrupting Carbon

Imagine sitting on a 30-year inventory of horse carriages in 1908 as Ford releases its Model T. Perhaps not unlike sitting on an inventory of gas-guzzling SUVs as Tesla enters the market now: an iPhone-like niche product ... with the potential to reshape the global transportation and energy landscape.<sup>10</sup>

The great *carbon age* that fueled global industrialization is waning. The emerging era of disruptive innovation will leave no industry untouched. While we will continue to consume carbon-based fuels for decades, the industry's test days are behind. The worst offenders are dying (e.g., coal, Canadian tar sands) and only the most efficient producers will remain. Credit risk will increase, and we have already seen worrying tremors in energy and resource-heavy junk and emerging markets bonds. Oil-producing countries will see continued capital flight, and default, social unrest and geopolitical conflict is a real possibility. We've recently seen tremors in the transportation sector, as railways suffer from lower coal and oil cargo. Financials and insurers with carbon concentration are vulnerable. While still relatively unscathed, utilities face disintermediation from distributed solar. Even automakers that benefit from today's cheap oil face disruption from electric vehicles and ride sharing, not to mention carbon taxes.

## 11. Disruptive Deflation

Technological innovation lowers renewable energy cost exponentially. Solar panel costs have dropped by 99 percent in 25 years, and projected to fall another 40 percent in the next two years. The now famous "Terror dome" chart from Alliance Bernstein's research (Fig. 9) shows that solar is already more cost effective than carbon competition in many parts of the world. There is no escape for fossil fuels.

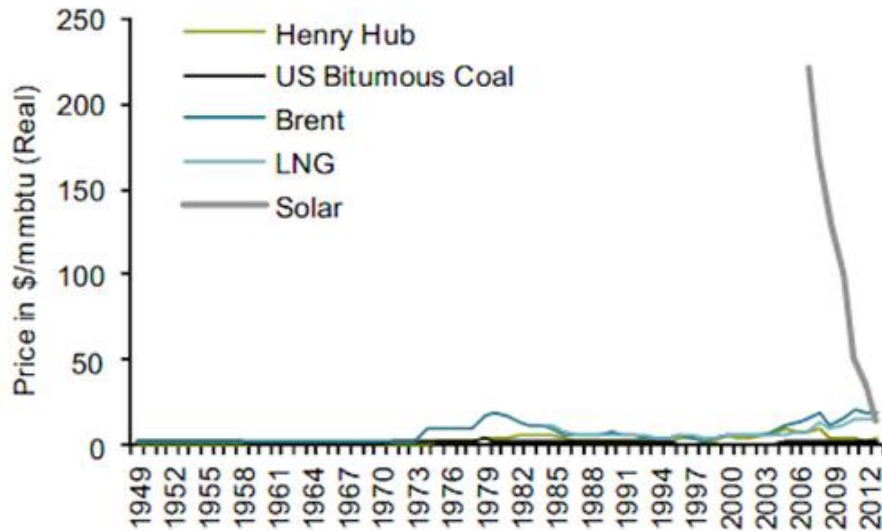
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<sup>10</sup> And indeed Apple itself has launched its own electric car initiative.

Fig. 9. Solar's cost curve compared to fossil fuels

Exhibit 2

Welcome to the Terrordome... \$/MMBTU by Energy Type

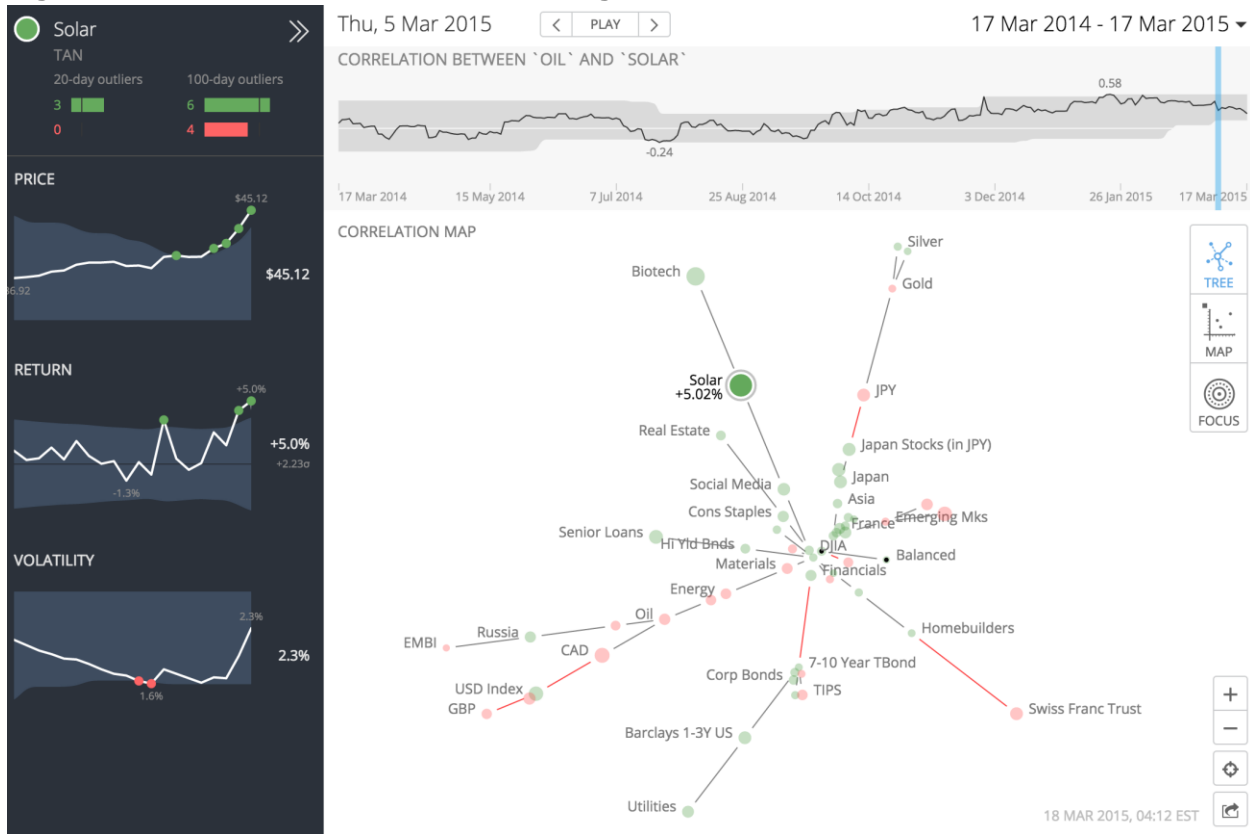


Source: EIA, CIA, World Bank, Bernstein analysis

Recent outlier clustering analysis from HeavyTails confirms solar's breakout and increased decoupling from oil. Fig. 10 shows that solar was the top HeavyTails outlier on Feb. 24,<sup>11</sup> March 4 and March 5, 2015 ... despite plummeting oil prices.

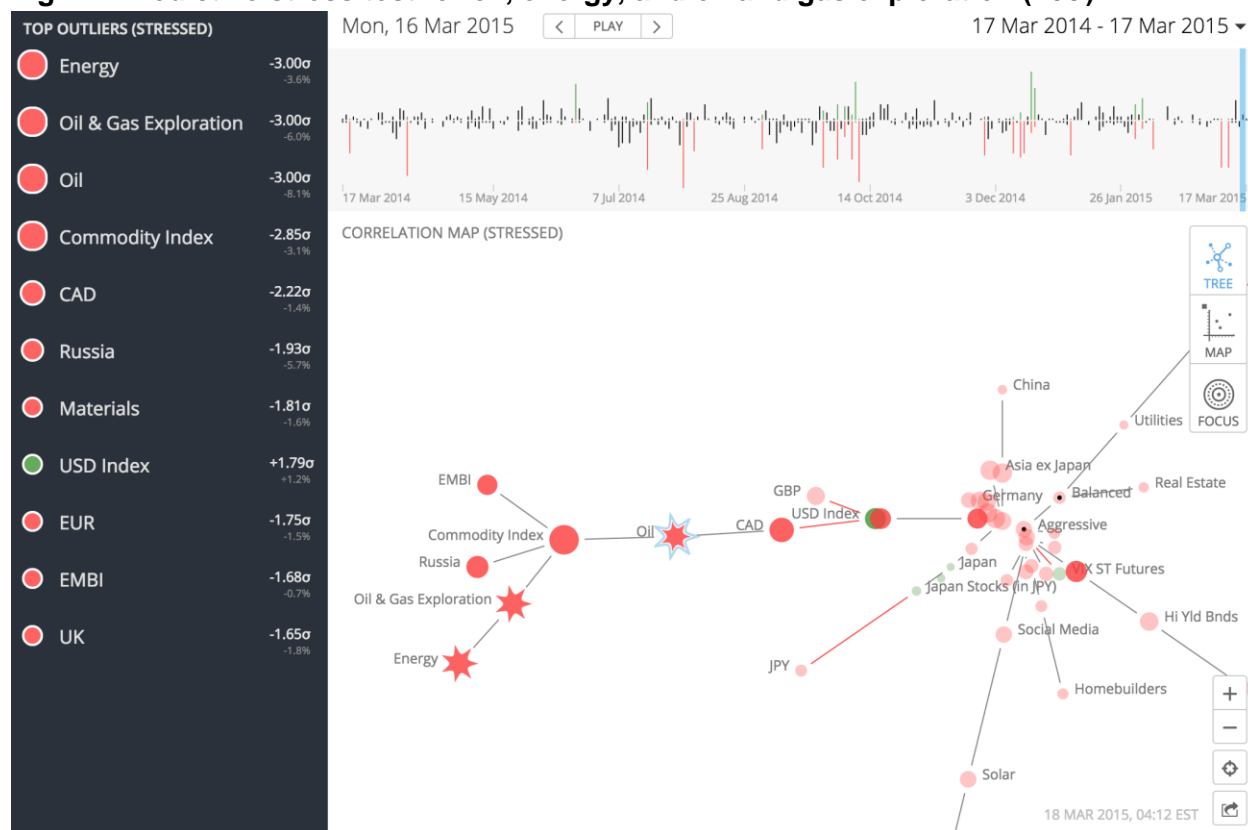
<sup>11</sup> The Feb. 24 outlier was triggered by First Solar/SunPower yieldco plans.

**Fig. 10. Solar's bull transition and declining correlation with oil**



Indeed, we have seen a continued decoupling of fossil fuels with broad markets since Nov. 28, Black Friday. Fig. 11 shows the predicted impact of  $-3\sigma$  shock on oil and oil exploration and energy as of March 18, 2015. Amazingly, this only impacts two assets beyond the  $-2\sigma$  level as broad markets have remained relatively immune (although clearly there will be systemic risk periods when correlations will recouple).

**Fig. 11. Predictive stress test for oil, energy, and oil and gas exploration ( $-3\sigma$ )**



## 12. Global Growth and Consumers Benefit

Despite turmoil from falling resource titans, we expect continued carbon decoupling as technology-driven energy deflation will benefit consumers and lead to sustainable growth. Homes, appliances, clothing, food and transportation will get cheaper. Developing countries will meet growing energy needs without sacrificing their environment; global productivity will rise as the bottom billion are connected to the basic resources necessary to thrive. Unless interrupted by natural or manmade disasters, the renewable energy revolution will spark virtuous cycles throughout the world.

## 13. Innovation Comes From the Periphery

We live in an ever-more complex and dynamic world, with disruptive technologies emerging rapidly across all industries. Top-heavy “predict and control” titans will increasingly falter, while agile players who effectively “sense and respond” to changing conditions will ride waves of opportunity. We can get a sense of emerging trends by observing startup and university ecosystems. Stanford University in particular has been an innovation epicenter and trendsetter. In May 2014, it became the first major endowment to divest, a moment Goldman’s former risk chief officer Bob Litterman described as a tipping point: “There’s going to be a lot of focus in the

next couple years on what is the social cost of carbon, how do we create appropriate incentives and, as investors wake up to the fact that this is happening, we're going to see more divestment, more investment in the next generation (of energy)."<sup>12</sup> Investment banks have already responded with "stranded assets total return swaps"<sup>13</sup> to facilitate this growing trade.<sup>14</sup>

## 14. Network Science Transforms Portfolio Management

Network science can empower dramatic changes. We will see a more connected picture of risk and develop our visual intuition to more effectively respond to changing market conditions. Network algorithms enable us to better harness social intelligence. As Scharmer and Kaufer (2013) describe, we are transitioning from "Ego-System to Eco-System economies." More will invest like venture capitalists, finding and funding disruptive enterprises, and sharing insights in trusted communities. Visual insights from *financial cartography* will be integrated with investment decisions, and portfolio optimization will reflect network characteristics like clustering and centrality. Backward-looking strategies will disappoint (e.g., buying resource stocks based on price-to-earnings ratio and book value). Network science will help us amplify intelligence from the leading edge of innovators and early adopters to make better capital allocation decisions.

## Conclusions

Risk managers have an increasingly critical role to play in this era of disruption. The 2014 fossil fuel meltdown sends important warning signals. The major systems that sustain us—economic, financial and ecological—are all vulnerable. We increasingly face challenges that affect us all, and risk management is a common good. Purely individual risk mitigation in crises such as stop-loss selling and liquidity hoarding only amplify systemic risk. Our best hope lies in leveraging mass collaboration platforms to better identify and mitigate risks. This is our aim with *financial cartography*, shared maps that leverage our twin superpowers of visual pattern recognition and communication. With these maps, we can effectively respond to emerging risks to protect our enterprise and ecosystem. This is our responsibility, as competent risk managers of the world. Let's help each other better navigate the seas of systemic risk with shared systemic risk maps.

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<sup>12</sup> Lawrence Delevingne, "Ex Goldman Risk Chief: Stanford Coal Cut a 'Tipping Point,'" *CNBC*, May 14, 2014.

<sup>13</sup> Bob Litterman, "The Price of Climate Risk," presentation, May 2014, <http://www.slideshare.net/theclimateinstitute/bob-litterman-may2014>.

<sup>14</sup> Feeling increasingly threatened, the Independent Petroleum Association of America (IPAA) sponsored research that argues the cost of divestment is huge ... based on a sample period of the last 50 years! The report completely ignores the looming impact of carbon limits and alternatives. See IPAA, "New Report: Divestment Would Cost Harvard, Yale, Columbia, MIT, and NYU More than \$195 Million Per Year," press release, Sept. 8, 2015, <http://www.ipaa.org/press-releases/new-report-divestment-would-cost-harvard-yale-columbia-mit-and-nyu-more-than-195-million-per-year/>.



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