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Thank you Mr. Chairman and members of the Committee for the opportunity to present some thoughts on the role of energy efficiency in the U.S. economy.

In one way or another, I've been involved in and studied the technologies of energy production and use for several decades. And in recent years, specifically in the pursuit of energy tech venture capital opportunities, I've had the privilege to talk with hundreds of entrepreneurs and companies involved in developing advanced energy technologies, and visited with dozens and dozens of them. This experience has made me quite optimistic about our long-term capability to meet the nation's energy needs – notwithstanding the caveat that there are substantial challenges in the near term.

The solutions to energy-related geopolitical, economic and environmental challenges are not going to be found in anything new in basic physics. The primary energy sources we have today are those we'll need to use for quite a long time – hydrocarbons, carbohydrates, sun, wind, water and uranium. Nonetheless, history will record that we are today on the cusp of an energy revolution – one involving efficiency -- with implications as deep and far-reaching as the industrial and electric revolutions of the previous two centuries. Each of those previous pivots in history was similarly anchored in profound changes in the efficiency with which we could use basic energy resources.

The emerging efficiency revolution directly derives from our nation's collective investment of trillions of dollars in the intellectual capital and infrastructure of the silicon and digital economy. It is not a single device, or solution, but the emergence of an entirely new structural approach to energy efficiency – *a hybrid energy economy*. The nature and implications of this technological paradigm shift are epitomized by the hybrid-electric car.

Conventional cars waste gasoline in stop-and-go, coasting, running unnecessarily at stops and generally operating an engine sub optimally. You could do manually much of what hybrids do automatically, though it would be annoying. Just turn the engine off every time you don't need it, at every stop, when braking, coasting, etc. Restart to accelerate or cruise. That alone increases a vehicle's urban fuel economy 10 to 50%. Or hybridize; wrap engine and driveshaft with sensors, power electronics, electric motors, batteries, microprocessors, software and high-speed communications buses – in short, all the stuff of the digital economy. Then let all that digital stuff seamlessly and invisibly juggle the on-off and optimally operate the constellation of energy consuming components, in real-time reacting to dynamic conditions, in ways you could never accomplish manually.

Nearly everything in our economy operates like today's cars – sub optimally. Building and running things in the physical world is difficult to do optimally. Compromises are always made to accommodate enormously varied conditions – compromises that have the collective impact of consuming more resources. The engineering challenge is to use just the right resources (largely energy, or the energy inherent in materials) at the right time and place. Cars are much simpler to fix in this regard than are factories, offices, and homes. Yet the latter, collectively, is where ***70 percent*** of our energy is used – sub optimally. Cost-effective hybrid energy technologies now emerging have potential for energy efficiency gains greater than anything in the transportation sector.

Enabling the emergence of the hybrid economy are the four inter-related domains of the silicon-digital economy: sensors, increasingly from nanotechnology, to collect information; high-speed communications networks; powerful microprocessors to crunch data; and high-power electronics to interface with the physical-mechanical world. It is only in recent years that all of these domains have achieved the necessary cost-effective capabilities to be deployed in the physical world. Sensors with astonishing sensitivity can be the size of dust motes and imbedded along with low-cost self-healing wireless mesh networks that enable microprocessors, costing literally pennies, to instruct high-power transistors to mediate the kilowatts required to move, form, shape and control physical things. This is what hybrid cars already use to achieve huge efficiency gains. It's what the rest of the economy can now do.

The technologies enabling a hybrid energy economy arrived first to serve markets for pure information systems, for data, voice and video. These came first, to put it simplistically, because information doesn't weigh anything, so the sheer power demands are relatively modest – pure information devices operate in milliwatts and watts. But you need kilowatts and megawatts to directly control steel, grain or people – to move tons of stuff instead of terabytes of pictures. Moving up the engineering power curve a thousand and million fold was difficult, and took time. It also took time to develop ultra-reliable software. A dropped call, or frozen PC screen is one thing – its equivalent in a factory, car, home, or hospital is quite another.

The hybrid economy takes America the next quantum leap beyond automation (already a $100 billion global industry), or supply chain information technology and such things as telecommuting and e-commerce. All are already responsible for energy-savings, but all are only building blocks to the deeper hybrid phenomenon -- the emergence of a capability to imbue the energy-consuming inanimate world around us with intelligence, communications and the ability to react and operate optimally. To simplify again with the car analogy; the automatic transmission which has been around since 1939 is a distant cousin of the innovations that make a 2008 hybrid car. A March 1956 *Time* magazine cover story touted, prophetically, the benefits of automation as the engine of growth. And it was for a half century. Overall U.S. energy efficiency has more than doubled since then, and our GDP increased six-fold – requiring a comparatively modest 2.5-fold increase in energy use. Now it's time for the hybrid economy to do the same, and much more.

Only a few years ago, the hybrid car was viewed as an expensive niche product. But it's already moving to the mainstream with the intersection of high energy prices and the (predictably) declining costs of silicon technology. So too the hybrid economy. Make all cars hybrid, and millions of barrels of oil are saved.

Hybridize the rest of the economy -- eventually everything physical that consumes energy to build or operate -- and billions of barrels are saved. The conventional wisdom is that the big gains in energy efficiency are behind us, the so-called "low hanging fruit." But technology also grows in cycles. We have yet to see the new crop.

Radical improvements in energy efficiency produce unexpected, beneficial outcomes. Energy efficiency is what made companies like Google and Apple possible. Operating at the efficiency of the first computers, a single Google data center would consume the entire electric supply of New York City. At the efficiency of early radios, iPhones would be trunk-sized and served by cell towers the size of the Washington Monument. Instead today, because of staggering improvements in computing and information energy efficiency, there are thousands of data centers, billions of computers and cell phones -- both are now ubiquitous industries with vast, productive sprawling infrastructures.

And while both have become major energy–consuming sectors in themselves –- collectively using more energy than the aviation sector –- the new digital technologies are, according to the Federal Reserve, responsible for one-third to one-half of GDP growth. They have thus added not only more services, features and wealth to the economy, but have done so at a fraction of the energy cost per dollar of GDP compared to the old economy. There is every reason to believe more of the same is in store with the next wave of efficient technologies emerging in a hybrid economy, but much of it inherently unpredictable in direction and form.

As with the hybrid car, the array of technologies – not to mention the constellation of players from large to small, traditional to start-up -- is broad enough to defy easy approaches to finding winners. The challenge, in fact, is the same for policymakers and investors. If there's a risk today in responding to immediate economic stresses of high energy prices, it is in the temptation to pick specific winners or paths, and to confuse true technology-based efficiency (with its deep, long-lasting benefits) from behaviorally-based conservation (which is largely evanescent).

Because efficiency – like its economic cousin, labor productivity -- arises primarily from technology progress, we face the now age-old challenge of finding ways to incentivize and accelerate innovative technology. How do we encourage markets to adopt near-term innovation, and find ways to invest in enabling infrastructure of long-term innovation? In both cases, money is the most powerful tool. High-cost energy accelerates near-term capital investment in more efficient technology. As for the long term, federal funding of basic R&D is essential to fuel the next cycle of innovation and to educate emerging innovators.

The future hybrid economy will be as different from today as the electric economy was from the industrial revolution that preceded it. But just as the 21^{st} century hybrid car is built directly from the 20^{th} century's automobile, so too the hybrid energy economy derives from the old. And while the challenges are global, it is clear at least from my travels that the United States will continue to be at the epicenter of this next great secular shift in energy technology.

Thank you Mr. Chairman, members of the committee. < >