THE NATIONAL ACADEMIES

MEETING SUMMARY

INFRASTRUCTURE

The Cost of Doing Nothing

Government-University-Industry Research Roundtable - June 24-25, 2013

From our highways, railways, and waterways to our electric grid, bridges, and schools, America's infrastructure is deteriorating rapidly. Despite the pressing need to repair and replace infrastructure, scarce resources in a depressed economy and competing priorities for funding have held back investment in repairs and new development. At this GUIRR meeting, participants examined how this underinvestment affects the economy and public safety and explored potential roles public and private entities could play in improving the nation's infrastructure.

The keynote address on June 24 was given by **Ed Rendell,** former governor of Pennsylvania and co-chair of the Building America's Future Educational Fund. It is no secret that American infrastructure is in trouble, said Mr. Rendell. Every four years, the American Society of Civil Engineers (ASCE) does an evaluation of the nation's infrastructure and in the most recent assessment, the U.S. got a D+. The good news is that five years ago America got a D, Mr. Rendell said; the bad news is that there were only six areas where America's infrastructure improved: rail, roads, bridges, sold waste, drinking water and waste water. What those six areas had in common was that each received significant stimulus funding, said Mr. Rendell. Pennsylvania, for example, received $1 billion in stimulus funding for road and bridge repair. Mr. Rendell as governor had already carried out a half a billion dollar bond issue for bridge repair, reducing the number of structurally deficient bridges from 6,600 (the highest of any U.S. state) to 5,200.

Because of this federal and state spending on infrastructure, Mr. Rendell said that during his tenure as governor Pennsylvania had the lowest unemployment rate of all the big industrial states. The U.S. Department of Transportation estimates that every $1 billion dollars spent on transportation infrastructure generates 25,000 jobs— a statistic Mr. Rendell found to be on target when he tracked the jobs created by the $1 billion in stimulus money given to Pennsylvania. If federal, state, and local governments together spent $200 billion a year more to improve infrastructure,

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as the American Society of Civil Engineers and Building America's Future recommend, Mr. Rendell estimated the result would be 4.5 million well-paying jobs.

In these difficult times, though, where would we find investment, asked Mr. Rendell. In the face of federal government inaction, he suggested that states have stepped up. The most startling example is Wyoming, where the Republican governor and legislature succeeded in passing a 10-cent increase in the gas tax; they understood that they need new roads to get the most out of the economic drive coming from the shale boom. Virginia, Vermont, and other states have also raised taxes for infrastructure spending. But getting the U.S. Congress to act is going to be difficult, said Mr. Rendell, because there seems to be a blanket idea that spending money is bad. However, given the magnitude of the infrastructure improvement costs and because many states are not willing to raise taxes, Mr. Rendell suggested that the federal government must continue investing in infrastructure.

Those of us outside the beltway need to impart to those in the Capitol that the cost of doing something is offset by the cost of doing nothing, he continued. The ASCE's report says that if we do not spend an additional $200 billion a year annually through 2020 to improve U.S. infrastructure, businesses will pay an extra $430 billion in transportation costs, household incomes will fall by $7,000, and U.S. exports will fall by $28 billion.

Infrastructure means public safety, quality of life, and economic competitiveness in Mr. Rendell's estimation. As the world shrinks, Pennsylvania doesn't just compete against West Virginia, New Jersey, and Ohio anymore; it competes against Singapore, India, China, and Germany. We're losing against our competitors, said Mr. Rendell, and one of the reasons we're losing is that our infrastructure cannot meet current demands. For example, the Panama Canal is being deepened, which will allow a new breed of supertanker to go through the canal and up the East Coast. The tankers need at least a 50-foot dredge to go into a port, and of the 12 major U.S. Atlantic ports, only two will be able to accommodate those new supertankers when the ships are ready next year. That means that most of the traffic will go to Newfoundland and Nova Scotia, and Canada will get all of the longshoreman jobs and trucking jobs that come from it. That's the price we pay, Mr. Rendell said.

In 2005 the World Economic Forum ranked U.S. infrastructure as the best in the world, but by 2012 we had fallen to 14th best in the world. Our rail systems are 18th in the world, our ports are 19th best, and our air transport system is 30th in the world because we are still using old radar-based navigation systems. It's easy to fix, said Mr. Rendell. When you fly, you pay a tax to the federal government called a passenger facility charge; you never see it, it is subsumed in your ticket price. If we raised the passenger facility charge by $15, that would generate $1 billion dollars a year. If we pledged $1 billion dollars a year to a bond, we could build the next generation air traffic control system in a year—a step that would yield enormous benefits, cutting the cost to businesses for flying people and cargo planes.

It's simple: this is the way to keep us economically competitive, said Mr. Rendell. The longer we delay, the price tag will go up, because construction costs are starting to increase fairly rapidly. The second reason to do this now is that many other developed countries—including Brazil, every EU country, China, and India—are doing it. Unless we want to become a second-class power, he concluded, it is time for us to act.

The first presentation on June 25, "Failure to Act: The Impact of Current Infrastructure Investment on America's Economic Future," was given by **Patrick Natale,** executive director, chief staff officer, and secretary of the American Society of Civil Engineers. We've been talking about infrastructure for a long time, Mr. Natale said, but we need to start seeing some action—by Washington, the states, regions, and cities—and bold leadership will be needed to make it happen.

Mr. Natale explained ASCE's report card, which is released every four years, most recently on March 19, 2013. ASCE evaluates 16 categories of infrastructure— how much money is being invested, whether infrastructure is improving or declining from the past, and analyses by experts based on data from the federal government. This year ASCE released an app which provides data on bridges and roads and levies; a user can find out information on his or her state, in terms of grades, problems, and success stories. (See www.infrastructurereportcard.org for more information, or visit the Apple or Droid app store and search for ASCE report card.)

America's overall grade is a D+, Mr. Natale said, noting that there are some pretty negative situations in various sub-categories; there are a few Cs, 1 B, and a lot of Ds. As some have said, though, it's a

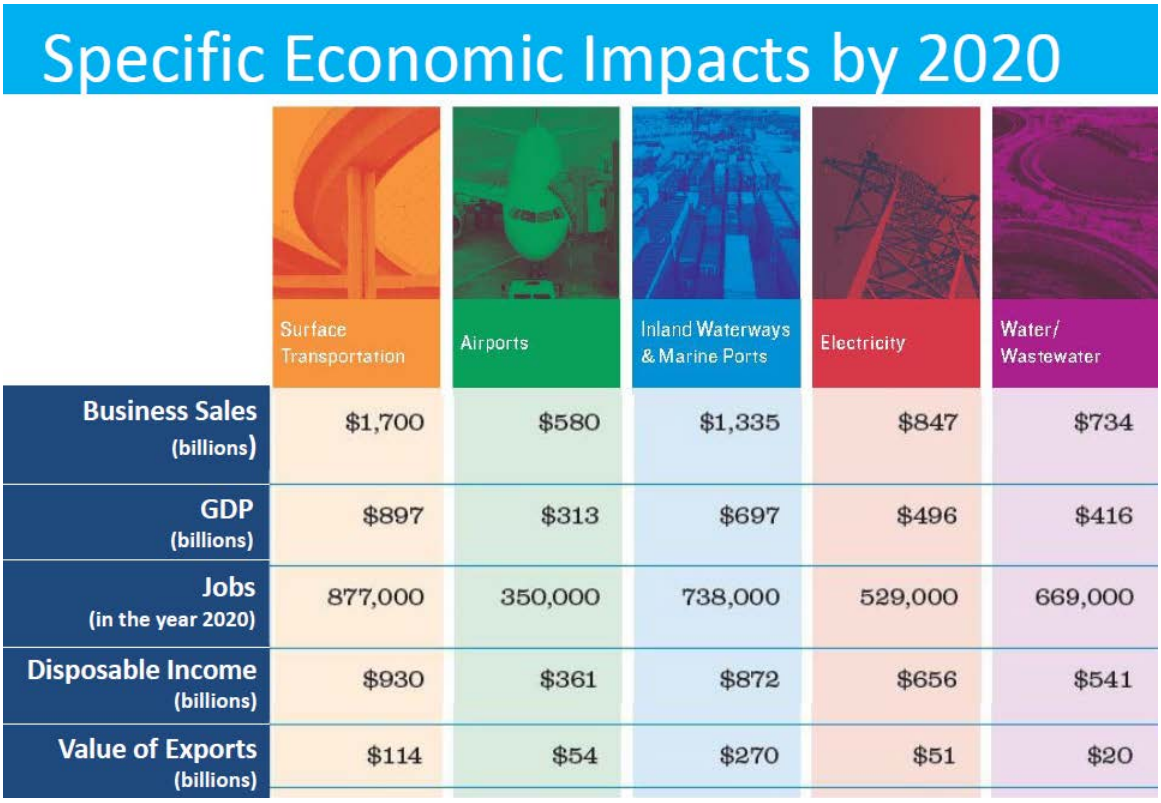

Figure 1 Specific Economic Impacts by 2020
SOURCE: Presentation by Patrick Natale, American Society of Civil Engineers, June 25, 2013

"tiny triumph." Grades in six categories went up because money was invested to move forward. Many roads were paved because of the stimulus package—a short-term infusion that is not sustainable—and rail went up because it received $20 billion annually in private investment for a number of years.

Mr. Natale also discussed ASCE's analysis of the amount of investment that will be needed for infrastructure between now and 2020. The total needed overall is $3.6 trillion, and existing funding mechanisms can produce about $2 trillion. So the gap that needs to be filled is about $1.6 trillion, which over a period of time comes out to about $200 billion a year. That does not all need to be provided by the federal government, suggested Mr. Natale; it needs to come from a combination of federal, state, local, and private money, as well as user fees. That's doable with leadership, political will, and a plan, said Mr. Natale.

The ASCE also studied the impacts if the U.S. fails to take action and invest in its infrastructure (see Figure 1). Not making these investments will be a drag on the economy, said Mr. Natale.

The total impact if we don't invest would be a $3.1 trillion loss in GDP, a $ 1.1 trillion loss in trade, a $2.4 trillion loss in consumer spending, and a drop of $3,100 in household income. (These figures only include losses from 9 of ASCE's 16 infrastructure categories, he noted.)

We need a world-class infrastructure system to meet the needs of this country, said Mr. Natale; the cost is not only economic but in terms of loss of life, such as with the levee failure with Hurricane Katrina or the bridge collapse this year in Minnesota. We need to take action—to get the message out to Congress, to the states, to counties, and to cities—and speak up about the importance of infrastructure and advocate to make our country number one again, because second best is not good enough, he concluded. He urged meeting participants to download ASCE's app and share it.

Next **Gabriel Roth**, research fellow at the Independent Institute, spoke on "Practical Ways to Improve U.S. Infrastructure Economically." First Mr. Roth raised the question of how economists and engineers would judge the benefits of investments, offering four criteria:

- **Willingness to pay.** Are the users willing to pay for the infrastructure that is being offered?
- **Subsidiarity.** Are decisions made by those closest to the problem -- by states rather than federal officials, by local officials rather than by states? National taxpayers should not be forced to support local facilities; it is difficult to justify farmers in Idaho being forced to subsidize the Washington Metro, for example.
- **Timing.** Are the more urgently needed projects tackled earlier?
- **Funding.** Are the funds available, and are they willingly paid, or are they taken from taxpayers?

Mr. Roth then suggested five next steps that he considered plausible ways to improve transportation infrastructure:

1) Choose investments that people are prepared to pay for. For example, express toll lanes and tolls that vary with traffic give people the choice to pay more in order to save time. Other examples are road improvements paid for by dedicated road funds and privatized air traffic control, as Canada has.

2) Choose private providers to maintain infrastructure to government standards. For example, in Britain private consortia were invited to build and improve roads in selected areas. Contractors of proven competence were chosen based on how little they were willing to accept per vehicle mile. Payment was tied to performance: the more the roads were used, the more the contractors were paid.

3) Remove the federal government from financing transportation infrastructure. Federal funding means that states pay to finance projects in other states, a system that encourages states to overspend at the expense of other states. Federal involvement also discourages private and other investments and can obstruct improvements desired at a local level but not federally supported, said Mr. Roth.

4) Raise state fuel taxes. These increases should be connected with establishing dedicated funds for specific purposes. A state would have a highway fund, for example, and the people running the state would get in touch with organizations of road users and work out what improvements need to be made and how to finance them.

5) Develop new, mileage-based ways for road users to pay for use. Mr. Roth stated that four years ago, a congressional commission unanimously recommended that new ways be found to charge for road use. People could be charged by the mile, as with your cell phone you are charged by the minute, with higher charges during congested periods. This seems to be a wonderful opportunity for government, industry and universities to get together to work on what is a very interesting technical and economic problem, said Mr. Roth. New methods can be piloted by road users who are given incentives to volunteer.

Adopting these recommendations, while difficult politically, could get users the facilities that they are prepared to pay for, at lower cost, more quickly, and better suited to customer needs, concluded Mr. Roth.

Next, **Barry LePatner** offered a presentation "Canaries in the Coal Mine: Why the 1-35W and I-5 Bridge Collapses are Prime Examples of What Happens When Infrastructure Goes Unfunded." Voices that warn about the need for maintenance for our aging infrastructure have gone unheeded, even as our bridges, dams, roads, seaports, airports and levees are sliding down a path toward unimaginable, inevitable, and unnecessary tragedy, he said.

While Mr. LePatner noted the problems facing the nation's highways and ports— and the billions of dollars the nation stands to lose because of these problems—much of his presentation focused on the risks posed by the nation's many structurally deficient bridges. While doing the research for his book *Too Big to Fall*, he obtained from the unpublished files of the Federal Highway Administration (FHWA) the identity of nearly 8,000 bridges that the FHWA recognized as both structurally deficient, meaning rated "poor" from lack of maintenance, and fracture critical—meaning that if one piece of the structure fails, the entire bridge goes straight down. These bridges included the I-35W in Minneapolis that failed on August 1, 2007, killing 13 and injuring 145, and the recently collapsed I-5 in Washington across the Skagit River (see Figure 2).

Each of the 8,000 bridges previously mentioned is going to face a similar fate as these two bridges and as nearly 600 other bridges that have failed since 1989, said Mr. LePatner, and when each of these bridges fails, it is going to cause untold damage to our economy and untold risk to the traveling public.

In a 2006 report, engineers told the Minnesota Department of Transportation (MNDOT) that they needed to fix the I-35W Bridge because it was fracture critical, structurally deficient, and would collapse. MNDOT rejected a range of possible fixes to the problem, saying that they were budget busters, Mr. LePatner explained. Then they found $3.5 million for a pothole repair on the bridge and allowed the contractor to load up right over those fracture-critical members 575,000 pounds of equipment and material, and the bridge collapsed.

In a perverse incentive that is going to be repeated each time we see this happen, said Mr. LePatner, the federal government immediately sent $235 million to MNDOT to build a state-of-the-art replacement bridge, and the engineering department of MNDOT won an award for building the bridge in 14 months. Instead of losing their licenses as engineers for having allowed that situation to occur, and instead of having criminal indictments for recklessly endangering the public, they were rewarded with a medal and a new state-of-the-art bridge, said Mr. LePatner. This is not the way our economy, our nation, or our infrastructure should go forward as the other 8,000 of these bridges that are going to fall are allowed to stay in that condition.

The list of structurally deficient bridges and other information gleaned from the FHWA's private pages can be found at www.saveourbridges.com, said Mr. LePatner; the site includes a Google map where any citizen can put in a zip code and find nearby bridges that are dangerous and should not be used.

Our sense of self-delusion in this area is massive, he continued, relating that he recently received an email from a former state transportation commissioner who admitted that he and other public transportation officials "made it a practice not to talk about bridge vulnerability in the public forum because it would be unsettling to the traveling public and cause anxiety."

What are the economics of fixing our nation's bridges? Funding for our failing bridges is based in large part on visual inspection by engineers—akin to asking your doctor to hold his fingers over your pulse to detect a heart condition, said Mr. LePatner. Advanced assessment technology exists but has been stalled in federal and state budgets. According to Mr. LePatner, using this technology would help identify tens of thousands of bridges that may not need remediation or may need less funding than expected because we can more accurately assess the condition of the bridge.

As we fix our infrastructure, said Mr. LePatner, we must change the way we do business with the construction industry. Ninety-two percent of transportation projects suffer cost overruns of 20 percent or more. In Mr. LePatner's estimation, we need to require the construction industry to sign fixed-price contracts and require them to assume the risk of delays--the public should not be paying for the inefficiencies of the construction industry.

A national infrastructure bank—a solution that has worked for many U.S. states— is also needed to seek funding from outside investors, because we do not have enough money from state, federal, and

Figure 2 Photos of I-35 W and I-5 Bridge Collapses
SOURCE: Presentation by Barry LePatner, LePatner and Associates, June 25, 2013

local governments to pay for what we've ignored for the last four decades. We also have to find ways to secure voter approval for transportation funding, Mr. LePatner urged; voters will pay higher taxes or user fees if they see their funds are going to a specific project or use that they benefit from.

In effect, we are not addressing just a political, or an economic, or a national security problem, said Mr. LePatner in conclusion; what we are confronting is a truly moral dilemma for every politician, transportation official, and infrastructure engineer in our nation. We are long past any rational time for us to say we must act, he said; we are teetering on very fragile ground, which like gravity will pull our nation toward inevitably tragic consequences.

Leading off a session on infrastructure funding mechanisms, **Chris Edwards,** director of Tax Policy Studies at the Cato Institute, noted that he is skeptical of the idea that the federal government needs to take a bigger role in infrastructure funding. The private sector already funds the vast majority of U.S. infrastructure; private investment in pipelines, freight rail, factories, etc. last year was $2 trillion—about five times more than the $367 billion spent by federal, state, and local governments.

So if we want more infrastructure, we should make reforms to encourage more private-sector funding, said Mr. Edwards, though he noted that government-sector infrastructure is very important to the economy. Interest groups often complain that there is not enough government spending on infrastructure, but that's an open question, he said. Total U.S. federal, state, and local government spending on infrastructure is about 3.5 percent of GDP, which is about average for OECD countries. Nor are today's spending levels really below the typical historical experience.

Even more important than the question of whether the government is spending enough is ensuring that funds spent are efficiently allocated. If funding flows to low-value projects, it doesn't help anyone or encourage economic growth, said Mr. Edwards, who pointed out several problems with federal infrastructure spending:

Investment is often misallocated because of politics. For example, Amtrak loses an enormous amount of money because politics has determined that Amtrak has to run many of its rail lines through areas with low population densities where there are not many riders.

Once federal funds are spent they are often utilized inefficiently. For example, the Bureau of Reclamation, which owns 250 dams in the 17 western states, provides water for irrigation at vastly under-market prices – much of the water is priced at 10 to 20 percent of its market value. This causes a huge amount of waste and overuse, and the west will face a real water crisis because the federal infrastructure is not a market based system, said Mr. Edwards.

General mismanagement and cost overruns on government infrastructure projects. When the federal government funds things like highways, it induces states to spend too much and spend on the wrong things. For example, many of the missteps on the Big Dig in Boston, which was about 2/3 funded by the federal government, happened because the state of Massachusetts, aware that much of the money was coming from Washington, lacked discipline to take measures to avoid cost overruns.

Federal involvement in infrastructure often replicates mistakes across the country. A classic example of this was high-rise public housing, in which the federal government invested huge amounts of money from the 1940s through the 1960s. The developments are now largely perceived as a mistake, but they were built because of federal funding. Instead, the states should be laboratories for infrastructure innovations, and states can learn from each others' experiences.

We ought to devolve infrastructure spending away from Washington and to state and local governments and private investors, said Mr. Edwards. Where would they get the money? From the usual sources -- taxes and user fees and debt -- but also through much more private investment. Private infrastructure works well because it can tap private markets to meet market demand. In contrast, government funding for infrastructure suffers from the politics and uncertainty of the federal budget process; a recent example is the cuts in funding to the FAA and the air traffic control system because of the budget sequester.
This can be contrasted with Canada, which in 1996 set up their air traffic control system as a private, self-funding corporation. The system has been hailed as a success, won numerous international awards, has one of the best safety records, and develops new technologies which it then exports around the world. It is a great model that we should be looking at here, said Mr. Edwards.

Next, **Michael Shapiro,** deputy assistant administrator in the Office of Water at the U.S. Environmental Protection Agency, explained how EPA works with states around water and

wastewater management infrastructure, offering a down-to-earth example of how infrastructure finance works in one specific area.

Often we refer to water and wastewater infrastructure as the poor cousins of the infrastructure world, since they don't have the visibility of highway or mass transit programs, but it's still a critical piece of the nation's infrastructure, said Dr. Shapiro. Public health depends on the availability of drinking water that meets public health standards, and the health of our aquatic ecosystems depends on treating wastewater. While the nation has made a lot of progress in these areas, drinking and wastewater infrastructure is aging like other parts of U.S. infrastructure, and a lot of it needs refurbishment or replacement. The ASCE report card grade for water and wastewater infrastructure was a D—a little below the nation's average grade. According to a recent EPA survey based on the project plans of municipalities, the nation's wastewater management infrastructure will require $298 billion in total funding over the next 20 years, and drinking water infrastructure will require $384 billion.

Since the 1980s federal funding of state water infrastructure has happened chiefly through state revolving fund programs, which represent a substantial devolution of decision-making to the states, explained Dr. Shapiro. In essence, EPA provides funds to capitalize a revolving loan program in each state, and the states contribute a 20 percent match. The money is used mainly to provide low-interest, low-market-rate loans to providers of wastewater management or drinking water infrastructure; the states then set priorities for where the money should go in order to meet standards, provide safe drinking water, etc. Loan repayments go back into the revolving fund, which lets the state gradually accumulate additional funding through interest accruals for future investments. States can also leverage the federal money in order to issue bonds to get additional funds.

In 2012 nearly $8 billion in financing was provided to 2,600 communities through the program, which is significant, though probably only 5-10 percent of the total financing, said Dr. Shapiro. Cumulatively over the life of the program, about $120 billion has been put into infrastructure, and much of that money is revolving. Through the stimulus fund, some money has been set aside for projects that improve the sustainability of wastewater and storm water management, such as the use of green infrastructure. Dr. Shapiro noted that existing infrastructure for wastewater monitoring works well for known pollutants but the impacts of what are known as "emerging contaminants" such as personal care products and pharmaceuticals are more difficult to gauge under current monitoring.

In addition to the revolving funds, certain proposals are being considered for ways to provide more funding for infrastructure—lifting the cap on private equity bonds that are used for public infrastructure, for example, or creating a national infrastructure bank that would use the borrowing power of the Treasury to provide additional sources of financing through loans or loan guarantees. While there is debate over how best to fund future improvements, this is a cost ultimately that we will have to bear in order to continue to provide the substantial public health benefits that our water infrastructure has historically been able to provide, said Dr. Shapiro.

The next presentation, "Infrastructure Productivity: How to Save $1 Trillion a Year," was given by **Mike Kerlin,** who co-leads the global initiative on infrastructure finance at McKinsey and Company. McKinsey estimates that $57 trillion in global infrastructure investment is needed in total cumulative dollars between now and 2030. If you were to take the total value of existing infrastructure, it would be like building it all over again, said Mr. Kerlin; however, practical steps can reduce infrastructure spending by 40 percent, saving $1 trillion dollars annually by boosting infrastructure productivity. This will require overhaul of infrastructure systems largely at the government level, as well as close collaboration with the private sector.

What are some of the challenges in getting to the needed $57 trillion? Mr. Kerlin identified four:

- **Fiscal pressure.** Government will need to reduce its spending by 10 percent to meet its debt-reduction targets.
- **Debt-to-equity ratios** that are no longer like the "good old days," when you could have 85 percent debt on a project. The cost of capital goes dramatically up if your 40 percent equity investors are going to expect greater returns that cause them to put a lower valuation on your project.
- **The shift to emerging markets.** The total spent on infrastructure by India and China together will likely equal the rest of the world combined in coming years.
- **An anticipated 30 to 80 percent increase in demand for commodities** in the next 20 years, which will increase commodity prices.

Can private financing fix these challenges? McKinsey looked at global pension funds, life insurance, and sovereign wealth funds under management, and they will likely climb to $106 trillion in 2030, but these funds are conservative and they are only targeting about 6 percent of asset allocation to infrastructure, so you still get to only a fraction of the need covered by these funds. The other big challenge is that while many investor clients are desperately seeking project pipeline, and many asset developer clients – U.S. municipalities, private sector infrastructure development, emerging market developers – are desperately seeking project financing or equity investment, there's not a match in terms of the risk-return profile investors are seeking. So private financing will partially solve the problem, but not entirely.

Reducing that level of need starts with infrastructure productivity, said Mr. Kerlin. McKinsey uses construction productivity as a proxy for infrastructure productivity and has seen that while all other sectors of the economy are growing dramatically in productivity, construction has fallen. McKinsey estimates there is a $1 trillion-a-year infrastructure productivity opportunity that would come from three big sources:

Improving project selection and optimizing infrastructure portfolios. When McKinsey worked with a state to try to figure out why they were getting less done for more money, they asked staffers in the state's preconstruction department (environmental permitting, civil engineering design) how they got assigned to projects. While their assignments were usually based on the project plan, they said, their actual day- to-day work depended on which board member was screaming the loudest. So McKinsey helped them create a prioritization system, one that took a quantitative and system-wide view. They also set up a small portion of funding that would be more discretionary; use of the funds still had to be justified, but it gave political interests a place to channel their energy without influencing the whole system. Also, while it is very hard to get funding for project planning, Mr. Kerlin noted, there an inverse relationship between project planning and cost overruns.

Streamlining delivery. The amount that can be done to reduce project cost by doing pre-construction planning more effectively and managing more effectively when the project is open is tremendous, said Mr. Kerlin.

Making the most of existing infrastructure. This could be done through demand management, operations and reduction of transmission/ distribution losses, and optimized maintenance.

Mr. Kerlin identified six enablers that can help government entities put these productivity drivers into practice:

1) **More data and accounting.** Take a balance sheet approach to infrastructure stock, so that you know how much you have and in what condition.
2) **More capacity and capability.** The right mix of strong leadership with high-quality project managers and planners
3) **Stakeholder engagement.** For example, seek input early in the process from a number of contractors, rather than having everything spec'd out before going out to bid
4) **Allow the private sector to propose projects.** Pursue private sector projects while having rules of the road so that it doesn't wind up being anti-competitive
5) **Getting the technocrat vs. politician balance right.**
6) **Coordination across institutions.**

Even if all of this is done right, there's still going to be a gap, said Mr. Kerlin, and one of McKinsey's next pieces of research is on how to make infrastructure finance less of a quantity question and more of a quality question. Mr. Kerlin suggested that sometimes infrastructure developers and owners feel a desperation to get financing without enough focus on getting smarter financing—right price, right time, right cost of debt—and that can mean billions of dollars for the government balance sheet and the economy, he said.

Next, **Janice Beecher,** a professor at Michigan State University and director of the Institute of Public Utilities, spoke about the utility sector. The Institute has a mission to support informed, effective, and efficient regulation of the public utilities that provide electricity, natural gas, telecommunications, and water. Dr. Beecher said the utilities that support the Institute do so because they are betting that well-educated regulators are better for their business in the long run.

While there has been an uptick in oil and gas, utilities have generally held steady at about 2 percent of the nation's GDP, and they need to think about moving toward a sustainability paradigm rather than a growth paradigm, said Dr. Beecher. Utilities have properties of both public and private goods, which makes them challenging; they are divisible and "priceable" to individual consumers, but in many cases they are provided most effectively through large networks that are often

monopolistic. Because the market is not there to discipline utilities in terms of performance, efficiency, and innovation, regulation substitutes for competition, and it needs to be a tough substitute. Utilities enjoy rights to a monopoly but in return are obligated to provide all paying customers with safe, adequate, reliable and nondiscriminatory service on just and reasonable terms. Utilities are not shielded from all economic risk; returns are authorized but not guaranteed.

When regulation is done well it can be a powerful tool, said Dr. Beecher. Regulators use three specific tools to motivate performance: **regulatory lag,** which utilities tend to dislike even though it focuses their attention on cost control; **prudence reviews,** which promote efficiency; and **incentive returns,** which reward innovation, although their use is controversial and it's important to avoid overcompensating for what the market or the investors will do in any case.

Right now there is tension and debate about modernizing utility infrastructure because we are building toward different energy futures, said Dr. Beecher. The question of scale, and whether the optimal scale is changing, is a question that keeps her and her colleagues up at night. Some people still believe in supergrids: the gigantic, interconnected grid subject to federal policy because it crosses state boundaries. An alternate possibility is the microgrid—smaller scale solutions and perhaps smaller utilities. There is also the possibility—a mind-boggling one for utilities—that we could move away from utilities altogether: What if solar roofs and fuel-cell technologies cause people to give up the grid altogether, leaving utilities with stranded investment and no future investment opportunities? Of concern is whether we can afford to build toward all these energy futures at once, said Dr. Beecher; this is where research can help us, because there are too many dollars at stake for us to be making too many plays at once.

Although the conference's theme—the cost of doing nothing—is right on point, said Dr. Beecher, there's also a cost to doing too much. We have to be very careful not to build tomorrow's infrastructure to yesterday's demand; technologies are causing demand and supply to shift in dramatic ways. One limitation of surveys like the civil engineering survey or the EPA survey is that they tend to take a rather static view of infrastructure, assuming that we'll replace every pipe and wire in kind. Infrastructure has to be understood as dynamic and responding to changes in demand, and there are opportunities for optimization and cost avoidance. Dr. Beecher thinks of the infrastructure spending gap as alligator jaws: we can work to close the gap from both the top and bottom. It's not just a matter of raising money: what are we doing about cost?

Looking at the EPA's community water system survey, half of the capital expenditures identified were for expansion, but community water demand is falling dramatically, said Dr. Beecher. Water efficiency is increasing, and urban water use per capita is down to what it was in the early 70s. Water managers from all regions of the country, have told Dr. Beecher that their number one problem is falling sales and revenue.

This is a success story in terms of efficiency and cost avoidance, but we've got to think about ways to re-optimize our utility systems, said Dr. Beecher. A prudent utility today considers operational efficiency, load management, reliability, public safety—and in particular at flexible, adaptable, and resilient infrastructure design. Rather than placing big bets on large power plants and treatment plants, utilities need to think about more modular and flexible options, because we don't know where the technologies are going. This is an exciting area of research, she said, and public-private partnerships to pursue this research would be very helpful.

The final speaker of the day was **Cyrus Wadia,** assistant director for clean energy and materials R&D at the White House Office of Science and Technology Policy. Dr. Wadia spoke about innovation in materials and the Materials Genome Initiative (MGI).

Advanced materials are going to play more and more of a role in our physical infrastructure, he said. Examples of such materials are bendable concrete, which uses embedded fibers to make it 500 times more resistant to cracking, and self-healing cement. It will be important to ramp up public-private partnerships and research to gain an understanding of both the fundamental properties of new materials and how to get them to market responsibly.

We need advances in materials to achieve many of society's goals, and when we frame the MGI we point to three broad areas of high growth: clean energy, national security and human health and welfare. The issue is that the time between discovery and market has been quite lengthy; everything from Teflon to lithium ion batteries has taken 20+ years to reach the market. We clearly have an opportunity to do better, said Dr. Wadia.

Right now the materials community is very fragmented, Dr. Wadia indicated, with many different materials classes and many different

industry players. There is no common umbrella that covers all materials classes and there are few incentives for tighter collaboration. This is what the MGI aims to change, said Dr. Wadia. Two years ago President Obama announced the initiative, saying that for the U.S. to be competitive in manufacturing, we need to shrink the time-to-market down from 20 years. We built this initiative with time in mind, and deliberatively chose a metric—time to market—that the government doesn't have the largest stake in. To reduce that time, we need to think about ways to bring university research and industry closer together. The initiative's goal is to get new materials to market twice as fast and twice as cheap.

How do we get there? The infrastructure piece of the MGI has three components: computational tools, experimental tools, and digital data. To be successful, we have to do two things well, said Dr. Wadia. First, we have to look at each of these components and do better. For computational tools, we have to improve predictive capabilities. On experimental tools, we need to think about investments in new techniques for characterization and development in manufacturing. And on data, we need to think about how to increase the fluidity of data so that it can support the types of knowledge and collaborations we want.

The MGI is about integration, said Dr. Wadia; we want to be more deliberate about creating public-private partnerships around specific problems in materials. MGI also wants to change the way people in the materials field think about their work, so that they see themselves not just as individual researchers or engineers but as part of this rich collaborative network that is collectively analyzing data and developing new tools. If these tools can be pulled together in a more integrated fashion, it may enable more materials to get to market faster.

The initiative is off to a running start, said Dr. Wadia. In fiscal year 2012 it had a $63 million budget funded by four federal agencies, and the majority of that funding has gone into new tool development and the integration concept. MGI needs to leverage those funds and use them as a catalyst by building closer tie-ins with other agencies and research programs, he said.

The initiative has also seen several million dollars of support from external stakeholder investments across over 60 different institutions.

These companies and universities and professional societies have all stepped up to the plate to do their own materials genome effort to connect with the MGI. A National Science and Technology Council subgroup has been chartered out of the White House to coordinate efforts across various agencies.

Dr. Wadia concluded by noting some news released on the program's 2nd birthday, which was the day before the GUIRR meeting. For example, NSF and DOE announced that day that they are teaming up to expand access to materials facilities to more industry and small- and medium-sized businesses, he said. The universities of Wisconsin and Michigan and Georgia Tech have created new materials initiatives individually, and this fall will team up to start a national dialogue about creating a National Materials Accelerator Network. In addition, Harvard and IBM released a database that allows users to look up properties of 2.3 million computationally derived materials relevant to organic photovoltaics. These developments illustrate the building momentum within the advanced materials community.

About the Government-University-Industry Research Roundtable (GUIRR)

GUIRR's formal mission, revised in 1995, is "to convene senior-most representatives from government, universities, and industry to define and explore critical issues related to the national and global science and technology agenda that are of shared interest; to frame the next critical question stemming from current debate and analysis; and to incubate activities of on-going value to the stakeholders. This forum will be designed to facilitate candid dialogue among participants, to foster self-implementing activities, and, where appropriate, to carry awareness of consequences to the wider public."

For more information about GUIRR visit our web site at http://www.nas.edu/guirr
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