Remarks of Prof. Jim Williams, University of San Francisco
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Our first panel today has the theme: deep decarbonization pathways – where do they lead?

The basic answer is that they lead us up some very tall mountains if we are to limit global warming to 1.5-2°C. The profoundly *good* news is that this is an achievable goal, using existing technology and at an affordable cost. This has been demonstrated by pioneering work on deep decarbonization pathways in the last 3-4 years, much of it conducted by people on this panel and in this room, and championed by Jeffrey Sachs and Laurence Tubiana, who spoke earlier.

The *sobering* news is that the actions required face serious challenges of scale. Clearly the fundamental scale problem is eliminating anthropogenic GHG emissions well before the end of the century.

Yet emissions trajectories alone – how many tonnes of CO_2 we can emit in year X – are not very revealing about what is actually required, which is the specific steps to achieve the transformation of the global economy, through a low carbon energy system and land use.

As these panelists have revealed through rigorous analytical work, the trajectory of that transformation can be described in more concrete terms like numbers of solar panels, EVs, heat pumps, LEDs, electric boilers – in what year, at what cost, dependent on what variables – that are much more tangible for political leaders, businesses, investors, and the public.

Still, the trajectory of transformation includes some steep climbs from where we stand today, and it is important to understand them. In the remainder of my time I'm going to introduce three key scale challenges – time, geography, and technology – and some implications for policy, planning, markets, and finance.

The first scale challenge is *time*. Not too long ago, there was a widespread belief that talking about emissions in 2050 and beyond was so far away in time as to be abstract and uninteresting to practical people. I think that belief is no longer so prevalent, because it is more widely understood that the economic lifetime of the most important infrastructure and equipment from an emissions standpoint – power plants, buildings, vehicles, factories – is on the order of decades, roughly the same as the time remaining from now to mid-century. When you recognize that infrastructure built now will dictate emissions in 2050, or else involve trillions in premature retirement & replacement costs, then future emissions must become a factor in investment decisions today.

The second scale challenge is *technology*. There are three pillars for decarbonizing the energy system in any country: energy efficiency, electrification of end uses that currently burn fossil fuel, and decarbonization of electricity itself. Economy-wide deep decarbonization is the result of combining these three pillars, for example switching from cars with internal combustion engines to efficient EVs, powered by carbon-free electricity. There are different technical options for doing these things, but all involve a long-term, large-scale deployment of efficient and low-carbon technologies – thousands of gigawatts of clean electricity generation, hundreds of millions of EVs and heat pumps, millions of new and retrofit buildings. That means large scale production and consumer uptake of these technologies globally, and it means continually driving costs down.

The third scale challenge is *geography*. This has two dimensions. One is vertical – cities nested in states nested in countries. Different levels of jurisdiction have different powers and responsibilities and capabilities. In the U.S., for example, the most important levers of control over the energy system lie at the state level. This is why pioneering states such as California can set their own emissions policies and carry them out. But cities and the federal government also have critical roles to play. The other dimension is horizontal – jurisdictions at the same level, whether they are physical neighbors like the U.S., Canada, and Mexico, or coalitions of the like-minded, such as states in the Under2 Coalition or cities in ICLEI and C40. Both vertically and horizontally, geographies are linked. Jurisdictions share physical infrastructure, like power grids; economic sectors, like manufacturing; and policies, like carbon prices.

Let me say a few words about the implications of these scale challenges for policy. First, the *timing* challenge – incorporating emissions consequences in the future into today's economic decisions, and preparing the infrastructure for the time that it's needed (e.g. charging for EVs when they become the main form of LDVs) means that we have to do long-term *planning*. Whatever right wing critics may say about planning being a symptom of state socialism, the expression "failing to plan means planning to fail" is a basic doctrine of successful capitalist enterprises, as well as successful government. Planning does not mean a rigid blueprint that fails to allow for the unknown; indeed, good planning enables us to think systematically about alternatives, contingencies, and uncertainties.

Second, the *geographic* scale challenge implies the need for *coordination* across jurisdictions. Making shared infrastructure and policies work together and not at cross-purposes is essential to the success of decarbonization. For example, most cities don't control their electricity supply; they will need to coordinate with state-regulated utilities and regional grid authorities to obtain low carbon electricity. At the same time, cities will drive demand through electrification of buildings and transportation. Planning, procurement, and operation of shared systems undergoing a low carbon transition will require coordination beyond what exists at present.

Third, the *technology* scale challenge requires *governance* of a new kind. For example, there simply aren't mediating institutions that link the electricity and transportation sectors, which surely will be closely linked when there are a hundred million EVs in the U.S. Dealing with everything from readiness of charging infrastructure to disappearing gasoline tax revenues requires new institutional solutions, both governmental and market.

Speaking of markets, they can be powerful tools but will need to be guided. For example, current wholesale electricity markets are poorly designed to handle a system in which the variable cost of energy is near zero – as in a system with lots of wind and solar – and is instead dominated by fixed costs. Our wholesale markets don't know how to allocate those fixed costs. Nor are these markets built to treat flexible demand– ranging from shifting the timing of household air conditioning to industrial-scale hydrogen production- as being equal in value to traditional generation resources for maintaining system reliability. Yet such a system is coming, and fixing these markets will be needed to coordinate procurement and mobilize the financing that a massive clean infrastructure buildout will require.

My final observation about policy in the face of massive timing, geographic, and technology scale challenges concerns the role of *analysis* in policy making, and specifically *pathways analysis* that addresses these scale challenges head-on. Long-term, all-sector, transformative, rigorously detailed analysis of the steps that must be taken, the technologies that must be deployed, at what cost, at what location, and at what level of jurisdiction reveals what policy actually needs to accomplish. Understanding what policy needs to accomplish is where policy-making needs to begin, rather than with *a priori* advocacy of any particular policy mechanism.

Enough people agree about the value of pathways analysis that it has had an outsized influence on the direction of climate policy in the last year or two. Paris Agreement Article 4.19, which calls for countries to develop mid-century strategies, recognizes their importance for both concreteness and ambition. There are currently mid-century strategies issued by six countries, including the U.S. (under the Obama Administration), Canada, and Mexico. In the U.S., pathways analysis already guides state policies, as in California; provides an overarching strategy for NGOs, such as the one NRDC released yesterday ("America's Clean Energy Frontier"); and becomes a core part of the business case for climate mitigation, as illustrated by last year's Risky Business report ("From Risk to Return"). Similar things are happening in other countries. Returning to our panel theme, where deep decarbonization pathways can and must lead is to real-world implementation of transformational low carbon goals, guided by the most concrete analysis we can provide.