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EDITORIAL

Dialog on Science and Policy to Address the Climate Crisis to conclude the International Association of Research Universities Climate Congress, Copenhagen, Denmark

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This is not the usual Editor-in-Chief letter, namely one that focuses on the accomplishments of the journal—and for ERL they have been numerous this year—but a recognition of the critical time that we are now in when it comes to addressing not only global climate change, but also the dialog between science and politics. In recognition of the many 'tipping points' that we now confront—ideally some of them positive social moments—as well as the clear scientific conclusion that environmental tipping points are points of long-lasting disruption, this paper takes a different form than I might have otherwise written.

While the scientific body of knowledge around global environmental change mounts, so too, do the hopeful signs that change can happen. The election of Barack Obama is unquestionably one such sign, witnessed by the exceptional interest that his story has brought not only to US politics, but also to global views of the potential of the United States, as well as to the potential role of science and investigation in addressing pressing issues.

In light of these inter-related issues, reproduced here—largely due to the efforts of Paul Baer to transcribe a remarkable conversation—is a dialog not only on the science of global warming and the potential set of means to address this issue, but also on the interaction between research, science and the political process. The dialog itself is sufficiently important that I will dispense with the usual discussion of the exciting recognition that ERL has received with an ISI rating (a factor rapidly increasing), the high levels of downloads of our papers (for some articles over 5000 and counting), and the many news and scientific publications picking up ERL articles (in recent days alone *Science*, *Environmental Science and Technology*, and *The Economist*).

This conversation was the concluding plenary session of the 10–12 March International Association of Research Universities (IARU) Conference on Climate Change (http://climatecongress.ku.dk/).

Conference Chair Professor Katherine Richardson began the panel by reading the 'key messages'. She then she asked the panelists—Professor Stefan Rahmstorf, Professor Will Steffen, Lord Nicholas Stern, and Professor Dan Kammen to respond. After that, she invited the Danish Prime Minister, Mr Anders Fogh Rasmussen, to respond to the messages. Next there was a dialogue between the panelists and the Prime Minister, with closing remarks from the Prime Minister.

Key messages/structure for the synthesis

Key message 1: climatic trends
Recent observations confirm that, given high rates of observed emissions, the worst-case IPCC scenario trajectories (or even worse) are being realized. For many key parameters, the climate system is already moving beyond the patterns of natural variability within which our society and economy has developed and thrived. These parameters include global mean surface temperature, sea-level rise, ocean and ice sheet dynamics, ocean acidification, and extreme climatic events. There is a significant risk that many of the trends will accelerate, leading to an increasing risk of abrupt or irreversible climatic shifts.

Key message 2: social disruption
The research community is providing much more information to support discussions on 'dangerous climate change'. Recent observations show that societies are highly vulnerable to even modest levels of climate change, with poor nations and communities particularly at risk. Temperature rises above 2 °C will be very difficult for contemporary societies to cope with, and will increase the level of climate disruption through the rest of the century.

Key message 3: long-term strategy
Rapid, sustained, and effective mitigation based on coordinated global and regional action is required to avoid 'dangerous climate change' regardless of how it is defined. Weaker targets for 2020 increase the risk of crossing tipping points and make the task of meeting 2050 targets more difficult. Delay in initiating effective mitigation actions increases significantly the long-term social and economic costs of both adaptation and mitigation.

Key message 4: equity dimensions
Climate change is inherently unfair in many ways, and thus raises profound ethical issues. Climate change is having, and will have, strongly differential effects on people within and between countries and regions, on this generation and future generations, and on human societies and the natural world. An effective, well-funded adaptation safety net is required for those people least capable of coping with climate change impacts, and a common but differentiated mitigation strategy is needed to protect the poor and most vulnerable.

Key message 5: inaction is inexcusable
There is no excuse for inaction. We already have many tools and approaches—economic, technological, management—to deal effectively with the climate change challenge. But they must be vigorously and widely implemented to achieve the societal transformation required to decarbonize economies. A wide range of benefits will flow from a concerted effort to alter our energy economy now, including sustainable energy job growth, reductions in the health and economic costs of climate change, and the restoration of ecosystems and revitalization of ecosystem services.

Key message 6: meeting the challenge
To achieve the societal transformation required to meet the climate change challenge, we must overcome a number of significant constraints. These include inertia in social and economic systems; implicit and explicit subsidies of the status quo; vested interests and political powerblocks; ineffective governance and weak institutions; inappropriate and outdated perspectives and world views; and values and ethics not tailored to address these new challenges and opportunities.

Stefan Rahmstorf (SR): First of all, not everything is worse than expected. So that's the good news. The global temperature is rising just as expected. If you look at the trend over the last twenty years or so, of course there is natural variability, around that trend, there are some warmer years like 2001 to 2005 were above the long term trend, and then 2008 is a little below the long term trend. But global temperature is basically rising as expected, and that's very reassuring to me as a climate modeler, because we think global temperature is easy, we understand it well, it's simple energy balance, so we shouldn't be too far off.

But there are other components of the climate system that we don't understand that well, for example the sea ice behavior, the continental ice sheet behavior, the sea level, and unfortunately, in these components, where we don't understand them so well that we can confidently compute them, things seem to go faster and worse than we had expected so far. For example the shrinking arctic sea ice is actually declining much faster than in any of the climate models, and we also see that sea level over the last 20 years or so is rising about 50% faster than the climate models have projected.

Another reason for concern is that if you look at the history of this planet, climate changes—the natural climate changes in Earth's history, we find that past warm climates were significantly underestimated by models, for example the Pliocene, it was the last time in Earth's history where it was significantly warmer about three million years ago due to higher greenhouse gas levels. We can't quite reproduce how warm it was back then, especially in the higher latitudes. And we also find that climate changes in Earth's history often have been very abrupt, that's another thing that we can't quite reproduce in the models, and at this conference I've seen some interesting evidence as to why some aspects of the climate in the climate models may be systematically too stable, so that in the real world things might actually be more unstable than in our models. So I think I leave it here for the moment.

Katherine Richardson (KR): Will, would you have anything to add? And you might want to maybe say a little bit about, we say that temperature rises above 2 °C will be very difficult for societies to know what to deal with.

Will Steffen (WS): Yes, I think that one of the aspects again that Stefan referred to that is reassuring because we think we understand and that models predict the fact that extreme events will increase in frequency and intensity as the climate shifts towards higher temperatures and more energy basically at the Earth's surface. We're starting to see this now, we see it in terms of increasing floods in many parts of the world, increasing heat waves, the 2003 heat wave in Central Europe is a classic example. But there have been others. There was a fairly bad one recently in southeastern Australia. We see droughts and drying in many parts of the world. Ironically the planet overall is getting wetter. And again, that's exactly what you'd expect as temperature goes up—increasing evaporation, increasing water vapor content in the atmosphere and increasing precipitation. It's very uneven. And one of the points that I want to make, Katherine, is that human societies have adapted to the patterns of climate that we've grown used to in the Holocene. So, we're used to placing agriculture where there is water now. We're used to placing cities in general where there are water supplies. So even though the planet's getting slightly wetter, the patterns are shifting. And certainly some areas, in general those areas that are dry now, are getting dryer. Droughts are getting longer; they're more intense because they're hotter. And this is placing pressure on urban water supplies, placing pressure on agriculture in some areas, and so on. So that's one aspect that I think if we go above two degrees these extreme events will get worse.

The second aspect is one Stefan referred to. I think we'll greatly increase the possibility that we could trip some of these so-called tipping elements. Now there are small ones that are still reasonably significant, in terms of droughts and so on, but there big ones, like monsoon systems in South Asia, like the Amazon Basin

rainforest and so on, which according to our best understanding now become more vulnerable, the higher you go above two degrees. Now we don't know for sure but you can view the certainty in a way as something you need to handle in terms of a risk analysis. These are significant changes. Well more than one billion people rely on that South Asian monsoon. So if that starts to falter, that's an extremely significant change in the Earth system. Those are a few of the examples, Katherine.

KR: You brought up the question of risk, and I think it's worth noting at this point that a lot of people in here including a lot of the journalists here have said, 'Where are the skeptics? How come the skeptics aren't here? Why didn't you invite them?' Well first of all, we didn't really invite anyone, except the few plenary speakers that we've had, but the IPCC report actually says for the first time that they believe it's very likely—at least a 90% chance—that the climate change we're seeing at the moment is caused by humans. And I guess you could say, the message that's come across here is, we have no reason to dispute that conclusion from the IPCC, and it looks every bit as bad as the worst case scenario that they identified there. So that's not even really very interesting. The good thing about this meeting is that we've got more data; we can go back and check, we can check the numbers; we can look where we are, according to where the IPCC thought we might be going. So far so good, no new surprises, we have a problem. What's really interesting, I think, is what we can do about it. So I'd really like to turn a little bit now to try and ask, what can we do about it? I mean, we hear all the time that 'We've got an economic crisis, now guys, can't we just wait and put this on the back burner?' So, going into the key message about the fact there's no excuse for inaction, would you, Lord Stern, like to cast yourself over that one?

Lord Nicholas Stern (NS): There is indeed risk to inaction. We do understand the risks that we're running. We can't predict these things with certainty, but it's very clear that the risks are big. And we know that by cutting emissions and the concentrations that result from them, we can reduce those risks drastically, and we can look at the costs of cutting, and we can look at the overall patterns of growth and develop- ment which are likely to emerge. And we can come to a judgment as to whether we think that those actions are worthwhile in terms of the reduced risks that they bring. When we do that, the answer to the question I think is overwhelming. For one or two percent of world GDP for a few decades, we could keep overall concentrations in the atmosphere below 500 parts per million of CO_2 equivalent, and then, over time, bring it on down from there. The kind of reduction in risks that would bring, I think, most people, given the kind of description you can give of a world at five degrees centigrade, which would involve huge, hundreds of millions of people moving, and as a result, deep and protracted world conflict. We can describe the magnitude of those risks better, as a result of your work, and we know that we can cut the probabilities of those risks very drastically for relatively modest expenditures.

But looking beyond that, what sort of growth would it bring? This would bring low carbon growth. It's very attractive. It's cleaner, it's quieter, it's more energy secure, and it's more biodiverse. And it's growth. High carbon growth kills itself. First from the high prices of hydrocarbons, and then, more fundamentally of course, there's a very hostile climate that it creates. If we look forward to the next 20 or 30 years, the big growth areas will be low carbon technologies. This will be the story of the railroads, and electricity, and IT. But probably in terms of growth opportunities, still bigger. So if we look at the reduction in risk that we can buy for modest investment, and if we think further of the kind of growth path it can generate for us, I think that we should see the action as actually rather attractive, and indeed the inaction as inexcusable. This is a real opportunity here, and it's particularly an opportunity when we've got before us two or three years of a depressed world economy, or a recession, or a slowdown, whatever description

you give. Resources over these next two or three years will be cheaper than they are likely to be looking into the future. Now's the time to get the unemployed of Europe working on energy efficiency, on making our houses more energy efficient. There's so much that we could do, and at the same time, lay the foundations for the kind of growth story that [lies ahead] I've had. We must not come out of this downturn by sowing the seeds of the next bubble, and that's what we did last time. We came out of the dot com bubble and we sowed the seeds of the housing bubble. We can do it very differently. We can come out of this one, and lay the foundations for a very attractive form of growth. So it really really is inexcusable not to take the action.

KR: So we need to invest the money, and we can get something out of investing the money, but Dan, what should we invest it in?

Dan Kammen (DK): Well that's what I think is so frustrating about this. We've heard a number of world leaders from international groups such as the UN Environmental Programme, to a number of centers around the world all highlighting that this is an opportunity to really invest in a 'Green New Deal'. And the ironic thing is that we've been hearing the message from engineers, physicists, economists, policy makers for many years, that energy efficiency, as Lord Stern mentioned, is not only a sort of a suite of technologies and practices that saves you on carbon, but it also saves you money. Now that we are in an economic downturn, there's no better combination than reinvesting in human capital, generating new jobs, and also generating a process that leads into additional technologies. It's clear from the scientific base, that while we've begun to make light bulbs better, and water heaters better and smarter windows that themselves can tint at the right times etc, that we haven't even begun the integration of efficiency with the wave of new renewables, using smart sensors that removes the need for the conduit in many buildings. All of this is the sort of stuff that you put together exactly when you are investing in a green new deal, and many of these things have remarkably quick payback times. The rates of return of these projects can be remarkably fast when efficiency and these new clean renewables are put together.

The fact that we aren't doing it already is frustrating, and doesn't make a lot of sense. What it says is that we're really not learning. Econ 101 seems to be something that we all are failing, and maybe we should go back to all take Sir Nicholas Stern's economics class. The fact is that green jobs are not abstract, but real. We observe it in a variety of settings. And we don't just observe it in rich countries, and rich cities. We observe job creation through investment in clean-tech and innovation in poor communities, where investing in local technologies like better cookstoves, locally hand-done windturbines, it really has a variety of applications in exactly the places we need it.

And so, the technologies themselves are there, the practices are there, the economic opportunity is there. It's perfectly clear that we are failing so far the challenge to reinvent systems science. So there's a number of details, but the real story is that we have a great number of these technologies and practices in an early form right now. We really need to put them into practice. And the countries that are most concerned, and the communities, absolutely need to step forward to take the lead.

KR: If I could follow up a little bit on that, now we for many generations it feels like now, but for at least as long as I can remember, somebody's been trying to give me a guilty conscience because I don't turn off a light every time I go out of the room. Is that the way forward? I mean, how do people get into this equation? Is it my fault we're in this mess right now, and if I act as a person, will something happen now, or am I completely meaningless in all this?

DK: We tried during the energy crisis of the 1970s, when part of the solution at least in the popular historic press was that we would essentially put on an extra

cardigan and sit by the fire. We would somehow reduce quality of life. I think the opportunity now that we are seeing is that, as Lord Stern said, we can actually invent this new wave of prosperity if we really get going on it. We have to be serious, we have to integrate solutions, and we have to send the message to the private sector that this is the long term new direction, this is not the short-term fad, we're not going to see research and development budgets rise briefly as we've seen wonderfully in the United States in the last few months, and then tank two years or three years down the road. In fact, I'm most heartened by what I think is becoming the hallmark of the new Obama administration, and that's a new pragmatism, combined with reprioritizing science. And that combination is exactly what you need to do if you essentially want to have a new industrial revolution but this a very clean one. So my hope, and actually I think that the technology bears it out, it's not a case of, do I need to now remember to turn off the light bulb every time. Of course you do, but our mix of technology, and market signals, give us ways to do it that can be profitable from a whole variety of very small, mom and pop operations, to medium sized companies to the big ones, and it can be an equally good message for people in poor developing countries and the more affluent ones. And we have to rise [sic] all boats here. I guess the melting ice and the rising boats may send a tricky message, but it has to be one that is not increasing the equity problems. We have to decrease that injustice in the world right now.

KR: Does anyone else have a call on who 'we' is in this? This is what's worrying me. It's easy enough to sit here and say 'we should, and we should,' but who's we? Is it me when I turn off the light, or is it the business, or is it the Prime Minister? Who's we? Lord Stern?

NS: There are many parts to the 'we,' but I would follow up what Dan Kammen just said. The two big challenges of this century are fighting world poverty and managing climate change. And we succeed or fail on those two together. If we don't manage the risks from climate change, then we will create a physical climate so hostile, that the hard-won gains of development are very likely to be reversed. If on the other hand, we try to manage climate change by putting barriers in the way of people raising their incomes in the next two or three decades, we will fail to put together the coalition, indeed we will deserve to fail, to put together the coalition which is crucial. So the 'we' is I think first all countries moving together with particular respect for the challenges that the developing world faces in moving to low carbon growth, and therefore a big obligation on the rich world to support the climate change action plans of the poorer parts of the world. That way we can put together a real coalition, a partnership. But it's also true, going down, right down to you, Kathy, as you asked us to do, that people's understanding of responsible behavior does make a difference. My generation in the UK was told that drinking and driving was dangerous. You wished they'd noticed before, but there were cries of 'it's a violation of human rights' to stop the ordinary person—it usually was the ordinary man, because it was a man—the ordinary man going down to the pub, having a drink and driving, or a few drinks, and driving home. And that to interfere was a fundamental restriction on personal freedom.

That was a perspective of rights and responsibilities. That has changed. How has it changed? It's changed through information. It's changed through discussion. And discussion is crucial. And with discussion, with information, with challenge, people change their views of what's responsible. So the sticks and carrots, the prices and taxes that we economists go on about, and should go on about—ignore them at your peril—but they're not the only part [of] the story. And an understanding of responsible behavior comes from public discussion. It's part of democracy. It's part of political leadership. Part of participation. And I do think that's an important part of the story.

KR: Will—do you have a feeling about who we are?

WS: I just want to make one further comment to follow on from those. When we go home after a very exciting and enthusiastic conference like this, and we hit the reality of getting back in our own settings and see everyday life again, it sometimes seems impossible to make the kinds of changes Lord Stern and Dan are talking about. But on the other hand I think there's reason for optimism. Because just like in natural systems, where things are often non-linear, and you hit a tipping point and then suddenly the system shifts, I have a strong feeling this happens in human systems as well. And that as we have the sort of discussions that Lord Stern referred to, I think you reach a point where things simply become accepted. You don't smoke in inside places anymore. And that was probably even more sacrosanct than driving home when you were drinking. You went to the pub and had a cigarette as well as a beer. And we don't do that anymore, and this happened very quickly. And people said that was going to be the end of pubs—it hasn't been the end of pubs. So I think that ideas can go through society exceptionally quickly. I sense that after a few false starts, we're getting to the point now where we could see this tipping element reached, and then things may happen faster than we scientists think, and a lot of our dire projections may be rendered as deep history, hopefully just a decade down the tracks. So [what] I'm looking forward to nine months from now is perhaps, looking back, saying, well, Copenhagen 2009, that was really the turning point. It wasn't all solved there, but that's when humanity really decided they weren't going to tolerate this hostile climatic future, that we might face. So I'm guardedly optimistic that you can see strongly non-linear effects in human behavior as well as in these natural systems.

KR: Mr Prime Minister, I'm wondering after this round here where we've presented our findings and a few of our heartfelt feelings, whether you'd like to make some kind of a comment as to how maybe this could be used?

Prime Minister Anders Fogh Rasmussen (PM): Thank you very much Katherine. And thank you very much for giving me the opportunity to participate in this closing session of this scientific conference, providing political decision-makers with an update of our knowledge base on climate change. I acknowledge the many scientists present at this conference. It is not only impressive, but it also shows the determination in the scientific community to address one of the most challenging issues of our time.

From my point of view, your contribution is an essential part of the preparations for the climate change conference, as an input to the negotiations within these very walls in December. Your input is very helpful, and today you have presented me with some key messages, and I would like to give you a first political response and some reflections. You asked, Katherine, who is, or who are, 'we'. Well I think 'we' is each individual, but we need a political framework to operate within. And that's our task, to create this political framework.

Your first key message could be translated into 'urgency'. I'm pleased to note that you build upon and elaborate the key findings of the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. The key message is that recent observations confirm that the worse case IPCC scenario is being realized. This statement must of course be taken into consideration when we set the targets for the reductions of greenhouse gas emissions.

You point to the acceleration of the climate trends. The longer we wait, the worse it gets. At the UN climate conference in Bali in December 2007, a two-year roadmap was adopted. Copenhagen is the target. Some people and countries question whether it is realistic to agree to a global deal in nine months. I say, we must. Waiting a year or two will only make the decisions even tougher. I say, we stick with the roadmap, but we also have to realize that this will demand intense negotiations in 2009, and the very close involvement at the very highest level of government.

The second key message is 'direction'. You point to the serious consequences of climate change, not least to vulnerable societies. In Copenhagen, we must come

to an agreement that limits global temperature rise to two degrees Celsius. This means at least 50% reductions in 2050 compared to 1990. The IPCC has already made the recommendations, Nick Stern has made the calculations, and from what I hear today, we may have to go beyond 50%. Many developed countries have accepted the target, including their own obligation to reduce by 80% in 2050 compared to 1990. Most recently, President Obama has committed to this ambitious long-term target. I hope the whole world will join in the common endeavor and set 2 °C as the ambition for a climate deal in Copenhagen.

The third message is 'action'. You point to the problem of delaying action. 2050 is more than 40 years away. I do know that in particular maybe politicians have to be very careful in announcing their retirements, but I think it is a reliable prediction that most of today's leaders will be out of politics by 2050. But the task is not to leave for the next generation. We have to start now if we want to reach the goal in 2050. The European Union has committed to 30% reductions by 2020 as part of a global agreement. Other industrialized countries are still to commit to comparable effort. Developed countries must lead the way. They carry a special historical responsibility. But, as we all know, even if all industrialized countries cut their total emissions to zero, we would not meet the target in 2050. Therefore, developing countries and primarily the emerging economies will have to take actions as well. And I'm encouraged to see the determination of major developing economies to address the problem and initiate the transition to low carbon economic growth. Overall, these countries will have to make an effort reducing their emissions to some 15 to 30% under a business as usual scenario.

Your fourth key message is 'fairness'. You point to the fact that the worst consequences are likely to occur in countries with least emissions. Adaptation remains a top issue in the negotiations. Financial and technical support to poor and vulnerable countries is essential, if we want to avoid unforeseen social and political clashes in the future. The wealthier countries must assist them in capacity building, and in implementation of sustainable adaptation strategies. Furthermore we must find a financial mechanism to fund mitigation efforts in developing countries. That includes forestry as one of the key sectors. I would say that cost-effective, market-based systems are most likely to survive and thrive in the long run. It's also the most likely to provide adequate and truly additional financial resources. Cap and trade can drive private investments. We should look for innovative ways to ensure mitigation without threatening our economies and the right to development. And let me be clear on this point. In the long run, market based solutions will prevail. They may be framed in different ways, but do have one feature in common: we must put a price on carbon.

Your fifth key message is 'opportunity'. You point to the benefits and not just the burdens. I could not agree more. Low carbon societies must be our goal. I do not believe we have a choice in a world going to nine billion people by 2050. Energy is not just a commodity, but a liability to use. Energy efficiency is not a choice but an obligation. If we start deploying the technologies at our disposal we could get very far. If we encourage the development of more green technologies, we are almost there. The solution is at hand, if we disseminate these technologies globally, and adopt standards for equipment, fuel standards being right at the top. And turning to the current financial crisis, the world desperately needs good news about our economies. Business as usual is dead. Let us take the opportunity provided by the recession to redefine the future. Green growth is the answer to our climate problem as well as to our economic problems. Low carbon growth is a long term sustainable growth. And I fully agree with Lord Stern that high carbon growth kills itself in the long run. So let me put it this way: regardless of the discussion on climate change, a change of our energy production and energy consumption is necessary at any rate, because a low carbon economy is beneficial not only for the climate, but also for our energy security and for sustainable economic growth.

The sixth and final key message… [governance]. You point to the political, economic, and social constraints that prevent us from taking the right positions. A global agreement in Copenhagen is not just about tackling climate change. It will constitute a new era in multilateral relations. It will be a unique occasion to construct a global solution based on mutual responsibility to act and to assist. People demand action; governments must realize that it is in their interest to act. Governments will fall if they fail. Politics must not be in the way of necessary solutions. The world needs better governance.

So in conclusion, let me repeat the key messages. Urgency—we must come to an agreement here in Copenhagen here in December. Direction—we must set a long-term target. Action—we must commit to short-term efforts. Fairness—the rich must assist the poor. Opportunity—green growth is the future. And governance—if we fail to act, we fall.

Thank you.

KR: I wonder now we've had the sort of scientific version of the key messages, and we've had the political version of the key messages, I wonder whether the scientific part of the panel would like to respond. Are there ways to build bridges from the scientific version, what science does and deals with it, to the political version of the same messages. We talk about communication, that's what we talked about on the first day, this is all about communication between different groups, and now we have the scientists and the politicians saying exactly the same thing—I think—at the podium. Why don't we try and get a scientific response. Stefan?

SR: I'm well aware that scientists and politicians and the general public often use language in a different way, there's a lot of communication problems sometimes arising from that, and I want to just express a concern that I have that when politicians talk about the ambition of two degrees as you did, that that's considered an ambition, and in the end, if all goes reasonably well, we actually end up with three degrees of warming. Whereas I think, I want to emphasize that when as scientists we talk about those two degrees, that really is a kind of upper limit that we really should not cross. I personally as a climate scientist, I could not honestly go and tell the public that two degrees warming is safe. We're already seeing a lot of impacts of the 0.7 degrees warming that we've had so far. So I consider two degrees not safe, and John Schellnhuber this morning asked about the question 'Is Russian roulette dangerous?' and in Russian roulette you have a one in six chance of something terrible happening, I think that when we go to two degrees we probably have more than a one in six chance of really bad impacts occurring.

DK: One of the really key stories we heard in the Prime Minister's comments is this connection between opportunity and urgency and need is really one story. And so, I would like to add a personal note to this discussion.

I was married in a small Nigerian village in Ondo State, Nigeria. My Aunt there tells me that she is seeing the growing season for staple crops steadily changing. She sees the need for solar panels on rooftops, and jobs for local solar technicians. And there's not just a concern about climate, but there's a frustration that we're not seeing the full shift to this green economy, even where it really bears fruit. And so, some of the upcoming events that I think the scientific community needs to connect to make this full circle. Is that we have an event even in Copenhagen in May, and it's the world business summit on climate. And that's the sort of event where these scientific and political messages, brought in connection to the next and the current generation of innovative business leaders provides exactly what my aunt in a small village in Nigeria is asking for. She's asking for a series of opportunities and messages, to invest in clean tech, and she suspects that her village might not be the first place to invent it, but she's quite convinced that it's a place to put those into practice, and to discover the ability to

put solar panels on rural hotels, not just to keep the beer cold in the fridge, but also to do a cold chain for antibiotics. And the opportunity to marry these other benefits—health, local development—is one where the business community that is not in huge presence here, except for some really neat green leaders, needs to diversify. And those examples are tremendously powerful. The more transitions we get, of companies, and of partnerships between political leaders, the scientific community, civil society, really can change the equation. So it's not just about doing this to avert something, it's about creating that new green path. So that's what I hope we get out of this process.

NS: I was going to pick up very strongly on the language that Dan Kammen used right at the end, and that's the power of the example. If we want to bridge the science and technology, the economics and the politics, showing how it can be done is so much more effective than simply describing how it can be done. So the more we can in the rich world show what low carbon electricity looks like, show how it can be done efficiently, develop low carbon transport, design cities and homes in a way that are much more efficient, those things will be used as examples. And I've often been challenged, particularly in developing countries, with the observation, which is entirely understandable, which is, 'Look, we've seen the rich world's example in getting rich on high carbon growth. That we understand, that we can see. We have not yet seen low carbon growth.' Now those examples are starting to come, and we know that here in Denmark, there has been quite strong growth for quite a long period of time, there's very little increase in emissions. It can be broken, the link between growth and emissions. We know that. But the more powerful examples we get, that can be understood and taken forward in other parts of the world, and we will have to learn of course from examples that take place in China, India and elsewhere, there will be strong examples there too, but the more we get those examples demonstrated and shared, and we make it easy to do the sharing, the more I think traction we will get.

KR: You have to understand that I'm trying very hard to get Lord Stern to give me a crash course on economics on the side. Let me just see if I understand you correctly, Lord Stern. What you're saying is, instead of me feeling that I'm being a good citizen when I donate my old computer to some needy person in Africa and it gets sent, I pay to transport it down there, I probably would be better off investing in Dan's solar panels in Africa?

KR: We're very heavily taxed in Denmark! But what I'm trying to ask is, do we need to change our development, our whole thinking of development support?

NS: We should be supporting development which is shaped and driven by developing countries themselves. This is about working together to expand the options that people have, the technologies that are available, and there will be important resource flows that are necessary. Some of those will come through carbon finance, some will come through overseas development assistance, some of them will come through private investment, some of them will come through the various kinds of guarantee and insurance instruments available through the international financial institutions. We should be looking all of us, those in developing countries, those elsewhere, at how we can find these ways forward in terms of investment, and how we can find the funding to support them. Then there would be a real partnership.

KR: Mr Prime Minister?

PM: Yes, well, I need some concrete advice now. Stefan Rahmstorf said two degrees—the two-degree target—is not safe. So, now I need to know from the panel, can we as politicians still rely on the IPCC recommendations or not? What

you're telling me is it that we should set the bar even higher? I need to know that. And I'll tell you why. I have—we have had a very hard battle within the European Union, and finally we decided on the 2 °C target. It's been a real challenge to reach that point. And now you tell me 'it's not enough'. Now I need to know, and I need to know today, is it enough, or do we have to change this target, because it's fundamental. We have now nine months left before a very, very important meeting in this room. It will be a real challenge—and now I think the scientific world has to make an agreement with itself—what is the real platform for politicians?

KR: And here you see a beautiful example of miscommunication. Because Stefan Rahmstorf did not say it wasn't safe, he said, 'I can't say it is safe'. And here, this is where we get into these nuances.

PM: Yes, but as a politician, I have to make a decision.

SR: Yes. I don't think the IPCC anywhere says that two degree warming is safe. So I don't think I disagree with IPCC on this point. What I was trying to say is the two degrees is really an upper limit, and it's not something that, you know, we aim for two degrees but it's OK if we end up at three. That was my key message that I wanted to convey.

WS: Just a couple of points. One is, when you try to come to some number like two degrees, that's a judgment that uses science, but it's not for scientists to give you that number. It's a risk game, and how much risk society wants to take. Now I think as John Schellnhuber said this morning, the two degrees is sort of an interesting compromise. And I think also from the political side of the fence, it's very difficult for you to deal with a shifting target coming from the scientific community. A final comment: I think that we have to look at this not only as a risk game, but also as an adaptive management game. I think as the science changes, simultaneously the economics will change, the technology will change in the ways that Dan Kammen and Lord Stern have outlined. So I think a two-degree target is a reasonable target for Copenhagen for 2009. I suspect five years down the track the game on both sides of the fence will change and we'll deal with that as it comes. But I think we've got to get the ship moving, and get moving in the right direction, so I think two degrees is quite reasonable for a first target.

KR: So Mr Prime Minister, we'd be very happy if you'd just give us the two degrees, and we're not going to change it. Perhaps you would like to finish off on what you've learned?

PM: Yes, I thank you very much, because it's very complicated for me to operate in a room with moving targets. So thank you very much, that was my first question. Then, next question: on the basis of that, can I still work in the direction of 50% by 2050 taking into consideration that the developed countries should contribute with at least 80% reduction? Is it sufficient or not? Yes or no?

SR: There are good studies on this and they suggest that if you reduce 50% globally below 1990 by 2050, then you have something like a 50% chance of staying below those two degrees. So that's not a guarantee of staying below those two degrees. So I advise to take a more ambitious target if at all possible. Especially since that leaves us some room for maneuvering in case we find out things are worse. We need some safety margin. There is uncertainty in our science, and the uncertainty often works out in the direction that things turn out to be somewhat worse. We have underestimated climate effects in the past, so the larger the safety margin that we can build into this, the better it is in my view.

DK: I think we have to take actually the stronger version of the statement to be honest. The IPCC has done its best job to synthesize the published literature, and

not the fifty percent reduction, but the 80% reduction target, from the use of the current suite of models, indicates that if we can achieve this really historic—and I would compare achieving the 80% reduction from the 1990 levels really to an entire new industrial revolution—it's not a maybe we can shift, this is really a new thing to do. We have all these tools, but we need to do it. Eighty percent reduction, based on current best science, says that we are keeping a risk alive of between fifteen and thirty-five percent or so. That is an unacceptable number for any health insurance or auto insurance that any of us would purchase. So that 80% is like the two degrees. When Stefan said, I'm asking for two, but I'm not saying if we drift past it it's OK. We're really saying this 80% is a critical version of 'if you go above it', you are essentially saying, not only will we be in this really dramatically different regime, but also that we admit to ourselves that we have condemned the poor to suffer an even larger dose, because they will be the first to be affected, they will be the ones that we trivialize and avoid their suffering in this process, so we really are committing an extreme case of environmental and climate injustice if we don't go for this harder path.

PM: Yes, because I think I have the necessary information now to conclude the agreement. Well, I like to challenge scientists because I know that they always operate within margins of insecurity, or risk, but the margins you provided me with is much smaller than what I'm used to in politics, so I'm not scared about it. But understand me correctly; at the end of the day, here in Copenhagen, we have—as politicians—to make the final decision, and to decide on exact figures, I hope. And this is a reason why I would give you the piece of advice, not to provide us with too many moving targets, because it is already a very, very complicated process. And I need your assistance to push this process in the right direction, and in that respect, I need fixed targets and certain figures, and not too many considerations on uncertainty and risk and things like that.

So all in all I would like to thank you very much for this discussion, which I think has been very fruitful and helpful, and I would like to congratulate you on having conducted a successful congress with an impressive participation of the world's finest scientists. And I think science should be the basis for decision-making in this field. Politicians can only act on what we know, and therefore your contribution is central. And you have given me the results from your hard work. I will carry your paper with me when I engage with other leaders to let them know what science says. You have delivered the facts; now it's up to others to carry it on.

And let me sketch out the process that will take us back to this venue in December. The formal UN negotiations will continue with a number of sessions throughout the year. But to close the deal on this multi-faceted issue, we need to engage heads of state and governments. And I see three important stepping-stones to achieve an agreement. First of all, we need to engage the key players at the very summit level. This group should meet in connection with the G8 Maddalena summit in Italy in July. Secondly, the UN high-level meeting in New York in September must give important final guidance for the content of the Copenhagen agreement. And thirdly, from September to December, we need intense negotiations in the UN track to sort out the modalities of an agreement. To exert the highest pressure on the negotiators, I encourage leaders to come to Copenhagen in December to help close the deal.

And what could then be the framework of the agreement?

As we all know, climate change is a global challenge, it needs a global solution, and that is why we meet in Copenhagen in December. And I think an agreement should have three key elements: targets, funds and verification.

First of all targets. By 2050, global emissions must be down by 50% compared to 1990, and you know these numbers better than anyone, and I'm happy to learn that this is still our goal. I have noticed that you consider it the minimum, and we will take that into consideration.

We need a binding commitment from the industrialized world to cut emissions substantially below 1990 levels already by 2020, and by more than 80% in 2050. Developing countries should also reduce at least by 15 to 30% by 2020 compared to a business as usual scenario, and thereafter we need to see real reductions.

Secondly, we need an agreement on funding. The developing countries face a particular challenge. We must provide funds to the developing countries to help them to transform to low carbon economies. New technology will be crucial; forests and better land use must be part of the package. The funds should also help the developing countries adapt to climate change and facilitate dissemination of technology.

And then thirdly, verification. We need a reliable and transparent regime to measure, report and verify national and international actions, both in terms of mitigation and in regard to finance and technology. Transparency is also a precondition for effective market-based systems that can facilitate investment into the economies with the greatest reductions potential.

And then, after Copenhagen, where next? Because Copenhagen is not the end; it is the beginning of our path to 2050 and beyond. In Copenhagen we set the framework; we commit to take actions and to assist those that cannot provide for themselves. We commit to share technologies and to encourage their deployment. After Copenhagen, we must hold each other accountable. I call on the scientific community to follow the trends closely and help us adjust our course. We must not only focus on the obligations, but keep competing for the opportunities. The greener, the better. Denmark's goal is to be completely free of fossil fuels. I believe it is possible, with the help of science, and with the determination of government. I look forward to welcoming you in Copenhagen again. Thank you.

KR: I want to thank you all for coming here, and for all your hard work here in Copenhagen. I hope you've all enjoyed and learned from your time here in Copenhagen; we've certainly enjoyed and learned from having you here.