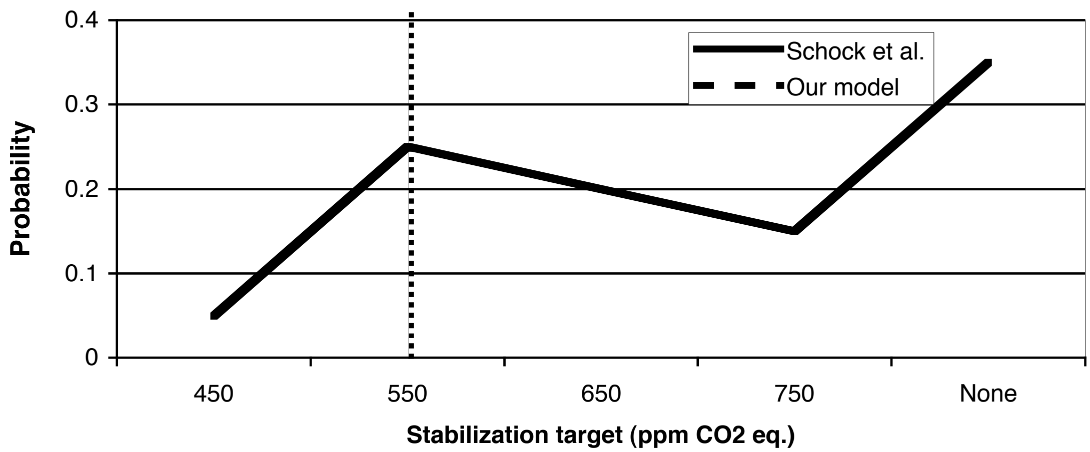
Supplement: Estimating energy R&D investments required for climate stabilization

This note describes the methodology used to arrive at the estimates for future energy R&D in Kammen and Nemet (2005). Schock et al. (1999) valued energy R&D by providing estimates of the insurance needed against oil price shocks, electricity supply disruptions, local air pollution, and climate change. By estimating the magnitude of the risks in each area and the probabilities of energy R&D programs to reduce them, they found that increasing energy R&D by a factor of four would be a 'conservative' estimate of its insurance value. We note that this estimate assumes a mean climate stabilization target of between 650 and 750 ppm CO_2 equivalent and incorporates a 35% probability that no stabilization at all will be needed. This possibility of no stabilization at all is especially concerning as it would potentially involve levels exceeding 1000 ppm CO_2 by the end of the century, with higher levels thereafter.



Probability density function for climate stabilization used by Schock *et al.* compared with the 550 ppm target used in Kammen and Nemet (2005).

A recalculation of their model to target the 550-ppm atmospheric level, scenario A1T ('rapid technological change') of the Intergovernmental Panel on Climate Change (Nakicenovic *et al*. 2000), increases the optimal R&D investment in energy R&D to \$11 to \$32 billion, 3 to 10 times the current level of investment.

Model Description

The model devised by Schock et al. establishes an "insurance value" of federal energy R&D. It is based on assessing risk mitigation due to R&D for four types of energy-related risks. The non-climate risks are discussed at the end of this appendix. The value of R&D for mitigating climate change is calculated according to the following:

The value of R&D for the U.S. (V_{US}) is the product of the climate mitigation savings derived from R&D programs (S), the assumed probability of R&D success (P), and the probability of needing to achieve each stabilization level (L). These values are summed for each stabilization level (i) and multiplied by the contribution to worldwide climate R&D by the U.S. (A).

$$V_{US} = A \sum_i (S_i P_i L_i)$$

Like Schock *et al*., we assume that the contribution to worldwide R&D by the U.S. (A) is in proportion to its current share of worldwide greenhouse gas emissions, approximately 25%.

The subscript i represents 5 greenhouse-gas stabilization levels: 450 ppm, 550 ppm, 650 ppm, 750 ppm, and the case of no stabilization.

The probabilities (L) of needing to stabilize at each level i, are used as shown in the figure above. For the Schock et al. model these are: 0.05 at 450 ppm, 0.25 at 550 ppm, 0.2 at 650 ppm, 0.15 at 750 ppm, and 0.35 for the case of no stabilization. In contrast to the probability density function used by Schock et al., we select the doubling of pre-industrial levels as our target and thus assign the level i = 550ppm a "probability" of 1.

We use the values developed by Schock et al. for the assumed probability of R&D success (P). These probabilities decrease with stabilization levels, under the assumption that lower stabilization will require larger contributions from early-stage technologies whose ultimate viability is less likely than near-term options. The range for 550 ppm is 0.5 to 0.8. We use both ends of this range to bound our estimate.

For each stabilization level i, the climate mitigation savings derived from R&D programs (S) is the difference between the costs to stabilize using the outcomes of a successful R&D program (CRD) and the costs to stabilize without the R&D program (C).

$$S_i = C_i - CRD_i$$

We use the costs to stabilize (C) calculated by Schock et al., who used the MiniCAM 2.0 model applied to two sets of mitigation scenarios, those by Wigley et al. (1996) and the IPCC. The cost to stabilize at 550 ppm is in the range of $0.9 to $2.4 trillion. It is important to note that these scenarios already include technology improvement, although they do not specify how much R&D is implied to achieve this "autonomous" improvement. As Schock *et al.* point out, if any of this assumed improvement depends on higher levels of R&D, the estimates calculated in this model will then underestimate the R&D required.

The costs to stabilize using the outcomes of a successful R&D program (CRD) are lower because the energy technologies developed in the R&D program can be used to offset greenhouse gas emissions at lower costs than using existing technologies. We use the assumption by Schock et al. that a successful R&D program will enable us to deploy technologies that produce energy at costs similar to business-as-usual costs while reducing emissions sufficient to stabilize at the 550 ppm level.

Data comparison

The table below shows the values used in the model. In our version of the model we use the same values as Schock et al. for the 550 ppm level. The one exception is the probabilities assumed for the needing to achieve each stabilization level (L). Our model is conditional on a stabilization target of 550 ppm, because we are deriving the amount of R&D required to achieve a specific target. In contrast, Schock et al. treat the stabilization level as an uncertain parameter with a known probability density function.

Parameter values used in the model

Study	Kammen and Nemet (2005)	Schock et al. (1999)				
Stabilization level	**550**	**550**	**450**	**650**	**750**	**None**
Cost to stabilize without R&D (C) $trillions	0.9 to 2.4	0.9 - 2.4	3.7 - 4.5	0.3- 1.3	0.2 - 0.5	0
Cost to stabilize with R&D (CRD) $trillions	0	0	0.4	0	0	0
Savings from R&D (S) $trillions	0.9 to 2.4	0.9 - 2.4	3.3 - 4.1	0.3 - 1.3	0.2 - 0.5	0
Probability of R&D success (P)	0.5 to 0.8	0.5 - 0.8	0.1	1.0	1.0	--
Probability of needing to achieve stabilization level (L)	1.0	0.25	0.05	0.2	0.15	0.35
U.S. share of worldwide R&D (A)	0.25	0.25				
Discount rate	0.05	0.05				

Outcomes

In our model, the total required spending was discounted and annualized to arrive at estimates for the required amount of annual federal energy R&D to stabilize atmospheric concentrations of CO_2 at 550 ppm. We arrive at a range of $6 to $27 billion in 2005 dollars.

Finally, we note that in their model, Schock et al. show energy R&D can be used as insurance against other risks as well, such as oil price shocks, electricity outages, and air pollution. Using energy R&D to mitigate these risks has an annual value of $9 to $10 billion. The figures above are perhaps overly conservative in that they assume that the R&D programs launched to address climate stabilization perfectly overlap with the programs used to address these other risks. A less conservative estimate would be to assume that perhaps half of the other risks would be addressed by the climate R&D program and half would not. For example, investments to improve the reliability of the electricity grid would reduce damages due to power outages but would not necessarily be included in a large climate R&D program. In that case, optimal energy R&D would rise to $11 to $32 billion per year, or roughly 3 to 10 times current levels. In our paper, we use scenarios of increases of factors of 5 and 10 to compare this range to the large R&D programs of the past.

References:

Kammen, D.M. and G.F. Nemet (2005) “Reversing the Incredible Shrinking Energy R&D Budget” Issues *in Science and Technology*, **22**: 84-88.

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