

How Much Could Kyoto Really Cost? A Reconstruction and Reconciliation of Administration Estimates¹

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Executive Summary

In December 1997, the Administration and representatives of 160 other countries negotiated the Kyoto Protocol, a climate agreement that commits industrial countries to reduce greenhouse gas emissions to a proportion of their 1990 levels. Implementing the Protocol in the United States would mean capping greenhouse gas emissions during the 5-year period from 2008-2012 at 7% below 1990 levels. The agreement authorized a form of emissions trading among industrial countries, but excluded developing countries from such trading and imposed no constraints on these countries' emissions.

The Administration has offered estimates of carbon permit prices and of the cost of the Protocol to the United States economy. These estimates appear to be much lower than those of many other analysts. The underlying analysis has not been released, but Administration officials have identified the assumptions under which results were obtained.

By working with these same assumptions and the economic model that the Administration used, Charles River Associates (CRA) has been able to adjust its climate policy model to correspond to the Administration's model and do three things:

- 1) Replicate the Administration's analysis and explain how its very low estimates for carbon permit prices and for GDP impacts were derived;*
- 2) Assess the Second Generation Model (SGM) that the Administration is using, and demonstrate that, with minor adjustments to the CRA model, it can reproduce the results of the SGM; and*

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3) Use the adjusted CRA model to show what happens if alternative and perhaps more realistic assumptions are used to estimate costs of complying with the Kyoto Protocol.

By undertaking these steps, CRA obtained the following results:

1) The Administration's permit cost estimates, which assume worldwide trading among all countries, show that the U.S. would be purchasing between 82% and 88% of its permits from abroad. The EU and others have objected to any country securing more than 50% of its permits elsewhere.

2) The Administration made a series of assumptions about cost saving from emissions trading. Removing the 40% saving that the Administration assumes from "umbrella trading" increases cost from \$7 billion in 2010 to \$12 billion. Removing the 55% saving from global trading increases the cost to \$27 billion, and removing the 50% saving from Annex I trading gives a starting point, for the cost to the United States with no international emissions trading, of \$53 billion. When all the Administration's assumptions about unrestricted emissions trading are removed, permit prices increase from \$14 per ton to \$193 per ton with no international trading.

3) The Administration's cost numbers take into account only costs in energy markets (direct costs). Most other models also take into account the impacts of higher energy costs in other markets (indirect costs), and derive estimates of GDP loss that are two to four times direct costs.

4) The Administration has assumed extremely rapid replacement of coal-fired powerplants by new natural gas plants by 2008. This is a very optimistic assumption about how rapidly large changes in natural gas infrastructure and power generation can be achieved, and there is some inconsistency between a very low permit price and achievement of these assumed changes.

5) Using perhaps more realistic assumptions about technology, fuel substitution, and the scope of international trading, permit costs of \$170 -- or about 10 times Administration estimates -- appear plausible even if there is a restricted form of international emissions trading. In such circumstances, GDP losses at least 10 times the costs derived by the Administration could occur, with similarly greater impacts on families, jobs, and businesses -- increasing the average household's energy bill by about \$850 per year and gasoline prices by almost \$.50 per gallon. Such impacts are consistent with the findings of others who have analyzed the likely impact of complying with the Kyoto Protocol.

Introduction

Administration Assumptions

Administration estimates of the cost of implementing the Kyoto Protocol are based on a number of important assumptions, including the ability to develop a global emissions trading system. Although the Protocol authorized emissions trading among Annex I (industrialized) countries, the nature of the emissions trading system and any limitations on the sale or use of purchased emissions permits were left to future negotiations. Moreover, the Protocol does not come into force until at least 55 countries--including Annex I countries responsible for 55% of 1990 carbon emissions--sign and ratify the Protocol. The United States has not yet signed the agreement, and the Clinton Administration has said that the agreement will not be submitted for Senate ratification unless there is meaningful participation by developing countries in a worldwide scheme to reduce greenhouse gas emissions. The Administration is also clearly counting on securing the cooperation of key developing and developed countries in an unrestricted, worldwide emissions trading system.

This may be a difficult task. A global emissions trading regime has never existed before, so some countries, such as Japan, are naturally cautious. Other countries, in particular the European Union, have made policy statements that appear inconsistent with the U.S. position. The United States favors unrestricted emissions trading, advocates inclusion of developing countries in such a system, and supports the intentions of Russia to market its anticipated excess of emissions permits in a fashion that would allow global emissions totals to increase. The U.S. position is in line with what most analysts believe to be the minimum requirements for an economically efficient trading regime. The European Union has recommended limiting the amount of permits a country could purchase to meet its emissions reduction target. EU members also object to the sale of excess permits by Russia and other countries. Moreover, developing countries have made it clear that they have no intention of joining an emissions trading system under the Kyoto Protocol.

Recent Testimony

In March 4 testimony before the Senate Foreign Affairs Committee, Dr. Janet Yellen, chair of the President's Council of Economic Advisers, presented the Administration's views on the cost of implementing the Protocol if the United States achieves all of its goals in future negotiations. Her estimates assume that the United States will convince other countries to create a comprehensive, global, and unconstrained emissions trading system that includes developing nations. Dr. Yellen's estimates constitute, in a sense, the best-case analysis for the United States, and are considerably lower than those in other recent studies, including work underway at Charles River Associates (CRA).

Understanding how responsible professionals can arrive at sharply different estimates of the same policy challenge is important. Fortunately, Dr. Yellen described in detail her assumptions regarding emissions trading, energy efficiency, and other cost-reducing factors. The differences between Dr. Yellen's analysis and other studies can be explained by honest and understandable

differences in these key assumptions. For example, in her testimony, Dr. Yellen said that fully implementing the Kyoto agreement would result in a direct cost to the 2010 U.S. economy of between \$7 billion and \$12 billion (1997\$). This figure represents about 0.1% of GDP in 2010, and would add between \$70 and \$110 annually in energy costs for the average American family. Dr. Yellen also estimated a price for carbon emissions permits of \$14 to \$23 per metric ton in 2010. Dr. Yellen's cost and carbon permit estimates are based on a set of extremely optimistic assumptions, including unrestricted global emissions trading and rapid replacement of coal with natural gas in electric utilities over the next 10 years. On the other hand, none of these estimates include credit for reductions in other greenhouse gases or credit for creating carbon "sinks" that might somewhat reduce costs in an extended analysis.

Dr. Yellen also stated that her cost estimates were based on the Second Generation Model (SGM), developed by Pacific Northwest National Laboratories. Although the SGM is a highly respected integrated assessment model, it has severe limitations for use in analyzing near-term economic impacts. In particular, the model reports only direct costs in energy markets, leaving out impacts on other markets and sectors of the economy that are included in virtually every other economic model used to analyze climate change policies. In its favor, the SGM is well documented and open to scrutiny, so that it is possible to identify the specific assumptions behind the reported cost estimates, and so to reconcile the estimates from the SGM with estimates from other economic models. Thus, it is possible to use other models to derive an estimate of overall economic impacts consistent with the direct cost reported by SGM and by Dr. Yellen in her March 4 testimony.

Adjustments to the CRA Model

When we introduce all of Dr. Yellen's assumptions into the CRA model, we get the same estimates of permit prices and direct costs as a starting point. But these assumptions and resulting estimates are extremely optimistic. The first necessary correction is to identify the impact of the Protocol on the entire U.S. economy, not just the direct costs of energy. When this is done, estimates of GDP loss, in our model and virtually any other complete model of the economy, produce impacts that are significantly higher than the estimates of direct cost provided by Dr. Yellen.

The second change involves estimating costs under different assumptions about fuel switching and under an emissions trading program consistent with the position of other countries. When these adjustments are made, U.S. costs to implement the Kyoto Protocol rise to ten times the amount Dr. Yellen estimates. In light of the current positions of other countries participating in the ongoing negotiations, this "adjusted" emissions trading scenario is at least as realistic as that assumed by Dr. Yellen. It assumes that developing countries do not participate in international trading; Russia is allowed to sell only permits generated by reducing emissions below baseline levels; and utilities are not able to replace all or almost all of their coal-fired powerplants with natural gas by 2010. Under these conditions, U.S. costs would be about 1.1% of 2010 GDP, or about \$110 billion (1997\$), and carbon prices would be about \$170 per metric ton (also 1997\$).

The outcome would be even more costly if Russia restricts its sale of permits to take advantage of its position as the sole seller under Annex B trading, or if the economy-wide price increases caused by higher energy prices result in a tightening of monetary policy and a further slowdown of the economy. If no internationally tradable permit system is implemented, the U.S. price of emissions permits would be \$295 per metric ton under CRA's assumptions, and \$203 per metric ton when Administration assumptions are used.

Baseline Emissions

The U.S. Energy Information Administration's (EIA) most recent forecast is that the United States will exceed the Kyoto limit of 7% below 1990 levels of carbon dioxide equivalent by 550 million metric tons of carbon in 2010. Table 1 reproduces EIA estimates of projected carbon emissions and Kyoto limits for the relevant global regions.

Table 1
Carbon Emissions in the Annex I Countries, 1990 and 2010,
and the Effects of the Kyoto Protocol in 2010

Country	Million Metric Tons Carbon				Percent Change	
	1990 Emissions	2010 Baseline Projection	2010 Kyoto Target	Reduction from 2010 Baseline	From 1990	From 2010 Baseline
Annex I Industrial Countries						
United States.....	1,346	1,803	1,252	552	-7	-31
Canada.....	126	170	118	52	-6	-30
Japan.....	274	342	258	85	-6	-25
Western Europe.....	971	1,101	893	208	-8	-19
Australasia.....	90	119	97	22	8	-18
Total.....	2,807	3,535	2,618	917	-7	-26
Annex I Transitional Economies						
Former Soviet Union.....	991	792	991	-199	0	25
Eastern Europe.....	299	280	277	3	-7	-1
Total.....	1,290	1,072	1,268	-196	-2	18
Total Annex I Countries.....	4,097	4,607	3,886	721	-5	-16

^a Includes Non-Annex I Countries. *IEO98* does not project emissions for separate countries within the EE/FSU region; however, Annex I countries in the EE/FSU region currently account for about 87 percent of the region's total emissions.

Source: Energy Information Administration, *International Energy Annual 1996* DOE/EIA-0219(96) (Washington, DC, February 1998), and World Energy Projection System (1998).

One of the subjects to be dealt with in future negotiations is how other greenhouse gas sources and sinks will be accounted for. Dr. Yellen cites Administration estimates to the effect that the Kyoto agreement will only require the U.S. to reduce its carbon dioxide emissions to 2 to 3% below 1990 levels when sinks are included in the baseline (see State Department briefing materials). However, in testimony before the House Subcommittee on National Economic Growth, Natural Resources, and Regulatory Affairs on May 19, 1998, Dr. Yellen stated that her calculations gave no credit for emissions reductions from sinks. Therefore, we take the EIA

estimate of 550 million metric tons² as the starting point for the calculations outlined in Dr. Yellen's testimony.

Emissions Trading Among Developed Countries

In her testimony, Dr. Yellen outlined two alternative international emissions trading programs and indicated these would reduce direct costs to the United States by 50% to 70%. These trading programs involve industrialized countries only.

- The first involved unlimited trading among all Annex B countries, including countries of the European Union, Russia and the Ukraine, and the United States. The Administration estimates that trading among all Annex I countries will cut direct costs by 50%.
- The second, referred to as the "Double Bubble" or "Umbrella Trading," assumes that the European Union will not engage in emissions trading with other Annex B countries, because of the prior establishment of an "EU Bubble" and allocation of the EU emissions limit among the EU members. The remainder of the Annex B countries would form a second bubble, trading only among themselves. The Administration estimates that this approach could cut direct costs by as much as another 40%, or up to 70% in total.

Additional background is needed to fully understand the Administration's underlying assumptions. In particular, umbrella trading would lower permit prices because it gives the U.S. favored access to low-cost permits from the former Soviet Union. Russia and the Ukraine are important sources of emissions permits, because their emissions in 2010 are projected by the DOE to be about 200 million tons below their emissions in 1990 (see Table 1 above). The collapse of the economies of Russia and other formerly centrally planned economies, plus more rational use of energy as they abandon subsidized pricing and move to market prices, leads to a projected drop in their emissions with no additional effort or cost. The Administration assumes that Russia and the Ukraine will sell these excess emissions permits freely, and that the supply of excess permits will depress the international price. However, Russia also could bank the excess permits for their own later use, thus reducing the availability of permits during the 2008-2012 budget period, or restrict sales to gain a higher price.

How much the supply of Russian permits will affect the international price of permits depends on the extent to which other Annex I countries bid up the price of Russian permits. In the Double Bubble option, with emissions trading limited to the non-EU countries, there are fewer countries bidding for Russian permits, and therefore the international price of permits is lower

² The CEA accounts for other greenhouse gases, but since Dr. Yellen's testimony does not explicitly state how other gases are treated, 550 metric tons is a best guess of what her starting point must be. This assumption essentially treats the inclusion of other gases as neutral.

than in the full Annex I trading case. This is responsible for the higher range of reductions assumed by Dr. Yellen in the bubble trading case, an additional 40% over the full Annex I trading case.

Emissions Trading With Developing Countries

Introducing emissions trading with developing countries, if they were one day to come under the Kyoto Protocol, would reduce permit prices further. The Administration estimates an additional 55% reduction in cost, over and above that achievable with Annex I trading, from inclusion of all developing countries in a comprehensive global trading system.

Summary Calculations

Taking all of the Administration's reputed savings at face value, the total cost reduction (without double counting) of implementing the Kyoto Protocol could be as much as 77.5% to 86.5%. Annex I trading cuts costs by 50%. Extending that to the rest of the world results in an additional 55%, or 77.5% in all. And in the Double Bubble case, costs are reduced another 40%, or 86.5% in all.

It is necessary to follow this train of reasoning backwards to reconstruct the Administration's presumed starting point, or estimate of permit prices and direct cost with no trading. According to discussions with CEA staff, the percentage cost savings in Dr. Yellen's testimony refer to reductions in cost, not permit prices. It is straightforward to estimate the costs that the Administration would have calculated for Annex I and no trading cases. This calculation is given in Table 2 below. Removing the 40% saving from umbrella trading increases cost from \$7 billion in 2010 to \$12 billion. Removing the 55% saving from global trading increases the cost to \$27 billion, and removing the 50% saving from Annex I trading gives a starting point, for the cost to the United States with no international emissions trading, of \$53 billion.

In order to calculate the permit price, it is necessary to apply the formula used by the Administration to relate direct costs to permit prices. That formula is derived from the SGM, discussed below. Direct cost equals one-half the permit price times the reduction in emissions plus the permit price times the number of permits purchased internationally. Thus, in order to calculate the permit price, we need, in addition to our estimate of direct cost, an estimate of the amount of permits purchased overseas. This estimate is provided by the SGM.

The results of these calculations are given in Table 2 below. A permit price of \$193/metric ton is consistent with a direct cost of \$53 billion and no international emissions trading. Permit prices for Annex I trading, global trading, and global trading with the "Double Bubble" are calculated using estimates of U.S. purchases of permits from the SGM. The results for permit prices under global trading fall within the range of prices reported by the Administration in March 4 testimony. All these prices and costs are in 1997 dollars, requiring an adjustment in results from the SGM and CRA models, which report costs in 1992 dollars.

The permit prices are derived from a formula used in the SGM that calculates direct cost from the carbon price, total emissions reduction, and permit purchases. For each value of direct cost, we used the SGM's marginal cost curve for carbon abatement to compute the corresponding carbon price and level of domestic emissions abatement. For a given level of abatement, the direct cost equals the sum of the area under the marginal cost curve up to the level of domestic abatement (see Figure 1) plus the transfer payments to foreign countries for carbon permits purchased. Therefore, we iterated over different levels of domestic abatement until we found the direct costs that corresponded to those in Dr. Yellen's testimony. Dr. Yellen's testimony is internally consistent. Applying the formula on carbon prices to the costs and assumptions outlined in her testimony produces carbon price estimates in line with those cited in her testimony. These calculations do not take into account any additional savings that could accrue from inclusion of other sources of greenhouse gases and credit for sinks.

Table 2
How the Administration's Permit Costs Dropped
From \$193 to \$23 or \$14/Metric Ton

Outcome	% Saving	Cumulative % Saving	% Of Emissions Reduction Obligation Purchased	Direct Cost	Carbon Price
No Trading			0%	\$53B	\$193/T
Annex I Trading	50%	50%	61%	\$27B	\$61/T
Global Trading	55%	77.5%	82%	\$12B	\$23/T
EU And Rest Of World Bubbles	40%	86.5%	88%	\$7B	\$14/T

Source: Yellen testimony and CRA calculations.

CRA's reconstruction of Administration calculations are buttressed by comparing the \$193/metric ton starting point with independent estimates made using the SGM that Dr. Yellen cited as her source of cost and permit price estimates. The SGM specifically finds that a tax of \$193 per metric ton would be required to reduce emissions by 550 million metric tons in 2010.

Review of SGM Model and Adjustments to CRA Model

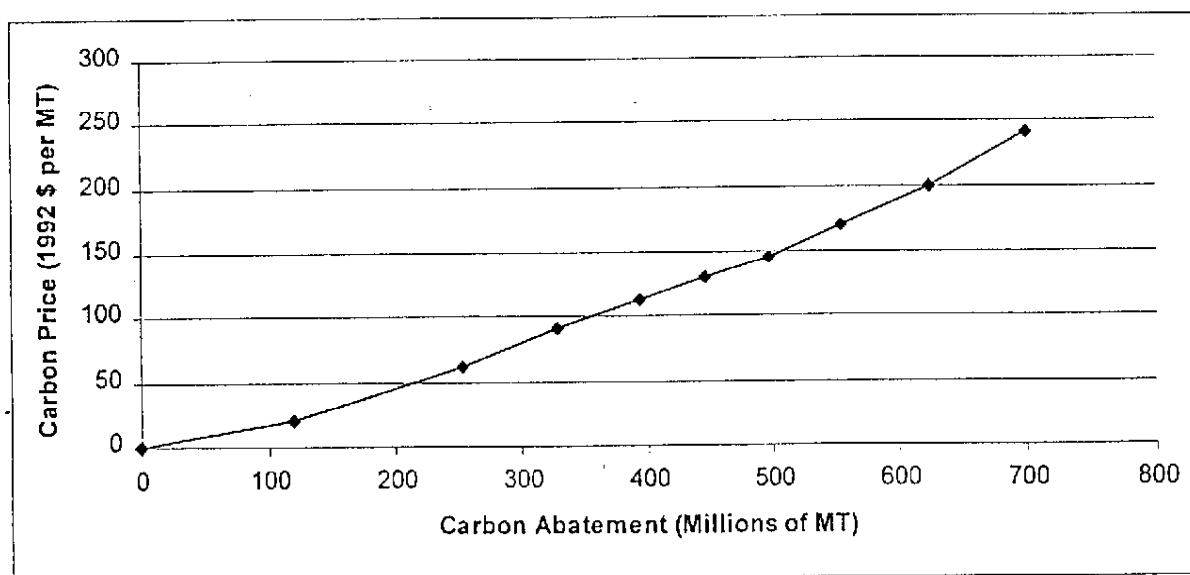
Dr. Yellen's March 4 cost estimates are based on the Second Generation Model (SGM), developed by Pacific Northwest National Laboratory. By taking the structure and results of the SGM model, the Charles River Associates (CRA) Model can be modified to produce essentially the same results, provided the same assumptions are run on both models. Once key elements of the two models are aligned, it is possible to run the CRA model as if it were the SGM model and discover the effect on the American economy of each assumption that the Administration used in

its analysis of costs. A number of these assumptions are very optimistic, and it will be shown that failure to achieve the Administration's assumptions substantially raises the cost of implementing the Kyoto Protocol.

SGM Model at Work

Figure 1 below is a reproduction of an October 1997 analysis performed by Dr. J. A. Edmonds and his colleagues at Pacific Northwest National Laboratory, using the Second Generation Model.³ Note that the figure focuses on the carbon price required to reduce emissions in the United States and identifies the amount of carbon emissions reduced (abated) as the price per metric ton rises. For example, a carbon price of \$7 to \$14 per metric ton (1997\$) would produce emissions reductions of about 65 to 100 metric tons in 2010 – or 12% to 18% of the U.S. obligation. However, a price of \$193 per metric ton (in 1997\$, or \$170 in 1992\$) is needed to achieve the full reduction of 550 million metric tons if the U.S. is unable to purchase emissions permits from other countries. *The \$193 per metric ton is exactly the same as the permit price implied by Dr. Yellen's testimony.*⁴

Figure 1
Carbon Prices and Emissions Reductions



Source: "Return to 1990: The Cost of Mitigating United States Carbon Emissions in the Post-2000 Period," J.A. Edmonds et al., October 1997.

³ "Return to 1990: The Cost of Mitigating United States Carbon Emissions in the Post-2000 Period," J.A. Edmonds et al., October 1997.

⁴ The October article reports prices in 1992 dollars, as does the CRA model. Dr. Yellen's testimony used 1997 dollars. For consistency with the Administration's estimates, SGM and CRA estimates are multiplied by 1.13 to change from 1992 to 1997 dollars.

The direct cost of reducing emissions in the United States can be computed by integrating under the marginal cost curve (or approximately the area under the marginal cost curve) by a triangle that has an area equal to one-half of the emissions abatement, times the permit price (0.5×0.550 Billion Metric Tons $\times \$193/\text{Metric Ton} = \53 Billion in 1997\$). This is the formula used in the SGM to calculate direct costs, and is also that used in Dr. Yellen's testimony.

We can also use these numbers to calculate the direct costs of reducing emissions under Dr. Yellen's assumptions. Her testimony refers to the SGM as the source of estimates of direct cost. The paper on the SGM describes how those costs are calculated--as the direct cost of reducing energy use plus the payments for permits purchased abroad. The formula used is one-half the permit price times the required reduction in emissions plus the permit price times the emissions permits purchased abroad. Table 3 below shows that, with these percentages of the U.S. obligation satisfied through purchase of permits, costs calculated with the SGM formula come out approximately equal to Dr. Yellen's range of \$7 to \$12 billion annually.

The SGM cost curve implies that if the permit price is as low as \$14 per ton, the United States will only reduce its emissions by 65 tons, or 12% of its obligation of 550 million tons. If the price is \$23, the United States will reduce its emissions by 100 tons, or 18% of its obligation. This leaves, respectively, 88% or 82% of the obligation to be satisfied by purchase of permits.

Table 3
Permit Prices and Emissions Reductions

Emissions Reduction (MMTC)	Permit Price (97 \$/metric ton)	% Permits Purchased Overseas	Direct Cost (MM 97 \$)	Permit Cost (MM 97 \$)	Total Cost (MM 97 \$)
550	14	88%	450	6,730	7,180
550	23	82%	1160	10,500	11,660

Source: Figure 1 and CRA calculations based on SGM formula.

These observations lead directly to the question of how reasonable are the SGM estimates of permit prices and costs. As noted, the SGM model leaves out the disequilibrium effects of a sudden energy price or energy supply shock. A closer look at the structure, cost coverage, and underlying assumptions of the SGM model will lay the foundation for reconciling its key components with those of the CRA model.

Overview of the SGM Model

The SGM is a widely respected model developed by one of the pioneers of analysis of climate change issues, J. A. Edmonds at Pacific Northwest Laboratories. The model is an ambitious integrated assessment model, which covers a time period of 200 years and includes a long-term technology assessment component as well as a sophisticated carbon cycle model that computes

impacts on carbon concentrations in the atmosphere. Within this integrated assessment model there is a simplified model of international trade and national economic impacts. The trade model includes the following 12 regions and 9 sectors:

Regions	Sectors
U.S.	Agriculture
Canada	Oil
Western Europe	Gas
Japan	Coal
Australia	Uranium
Former Soviet Union	Electricity
Eastern Europe	Refining
China	Gas T&D
India	All Else
Mexico	
South Korea	
Rest Of World	

Model Structure

The SGM is a long-term energy model that assumes costless, instantaneous adjustments in all markets except electricity generation. This is a perfectly appropriate approach when modeling transition costs among technologies and resources over a period of a century or more, but the model is an inappropriate choice for investigating economic impacts over the period of time between now and the first Kyoto Protocol budget period. Indeed, a report by the Interagency Analytical Team suggested that the SGM model was designed in a way that leads it to estimate costs at the low end of the range in 2010.⁵

The model also represents international trade rather simplistically. This makes the model ineffective when addressing issues of international competitiveness. In fact, the SGM model only determines the price of carbon emissions permits in international markets. It does not allow for changes in capital flows, "leakage" of investment and energy-intensive industries to countries not bound by the Kyoto Protocol, changes in world oil prices, or equally important indices of U.S. economic vitality.

⁵ "Economic Effects of Climate Change Policies: Results of the Research Efforts of the Interagency Analytical Team," June 1997, p. 11.

Cost Coverage

The SGM's greatest flaw, however, is the fact that it focuses solely on direct costs in energy markets. It ignores transition costs and indirect costs to the entire economy. This results in abnormally low estimates of the full effect of a change in the U.S. economy of implementation of the Kyoto Protocol. This is why Dr. Yellen stated her estimates as the "direct cost as a % of GDP (emphasis added)."

Studies of the total GDP impact on the U.S. economy of regulatory programs (such as Kyoto) indicate that the true costs typically exceed "direct costs" by a factor of two to four. Results similar to these have been reported by Jorgenson and Wilcoxon, using DGEM models to estimate the cost of air quality regulations, and by Kopp and Hazilla in work on the CRA model in the early 1980s.⁶ In short, unless the SGM's figures are properly qualified, estimates generated by that model may be one-half to one-fourth of the costs to the entire economy.

Assumptions Regarding Electric Utilities

The SGM model makes a critical assumption regarding electric utilities. Specifically, the SGM model compares the total cost of a new gas-fired powerplant to the cost of operating an existing coal-fired powerplant. The technology and fuel costs and heat rates in the SGM database lead to the conclusion that permit prices of just over \$100 per metric ton would result in converting all existing coal-fired powerplants into new natural gas combined-cycle units. Moreover, the SGM models allows all of these conversions to take place by 2010, with only a slight increase in costs (to approximately \$150/metric ton). This means that the carbon permit price cannot exceed \$150/metric ton until all coal-fired generation is replaced.

This is a very optimistic view of how rapidly (and how cheaply) existing coal-fired plants would be scrapped, especially in view of the uncertainties surrounding U.S. implementation of the Kyoto Protocol. If international trading holds the cost of carbon permits under \$25 per ton, utility executives would have no incentive to replace coal with natural gas. And if carbon permit prices rise above that mark, the replacement of current coal-fired powerplants would be a massive and costly undertaking. An extensive permitting and approval process for land use and environmental impacts would be needed to build the new plants. Moreover, natural gas exploration, production, and delivery all would have to be expanded substantially--and quickly--and natural gas prices would rise accordingly. Finally, coal producers and unions would likely respond to the threat of job losses by lowering their wages and/or insisting on the legal enforcement of take-or-pay provisions in existing contracts. Either of these responses could

⁶ Jorgenson and Wilcoxon (1992), "Impact of Environmental Legislation on U.S. Economic Growth Investment and Capital Costs." *In US Environmental Policy and Economic Growth: How Do We Fare?* Washington, DC: American Council on Capital Formation. Jorgenson and Wilcoxon (1993), "Reducing US carbon emissions: An econometric general equilibrium assessment," *Resource and Energy Economics* (15) 7-25. Hazilla, M. and R. Kopp (1990), "Social Cost of Environmental Quality Regulations: A General Equilibrium Analysis," *Journal of Political Economy* 98(4): 853-73.

significantly delay the building of new plants and change the economics of natural gas replacement of electric generating facilities.

This scenario is not idle speculation. MERGE, a model developed by Dr. Alan Manne and Dr. Richard Richels, also describes the process of electricity generation in considerable detail. Their model and others place constraints on the amount of coal capacity that can be replaced by 2010. In short, the SGM assumption that all coal capacity would be replaced by natural gas in such a short time does not appear to be tenable.

Energy Efficiency

Administration testimony also includes a discussion of the reductions in cost that are assumed to come about from improvements in energy efficiency. More specifically, Dr. Yellen assumes an annual rate of energy efficiency improvement (AEEI) of 0.96%, which is 6% above what the DOE Energy Information Administration used in calculating its *1998 Annual Energy Outlook*. CRA's replication also includes this assumed 6 percent higher rate of change in energy efficiency.

Kyoto Cost Estimates, Using More Realistic Assumptions

Now that the Administration's analysis of the costs of Kyoto to the U.S. has been replicated and the underlying assumptions fully revealed, we seek to ask what might happen if the same underlying analysis is applied but under different assumptions. The first step is to reconcile the CRA model with the results reported by the Administration based on the SGM model. The second step is to focus on the costs of implementing the Kyoto agreement under different underlying assumptions.

Reconciling the CRA and SGM Models

The CRA model produces nearly identical results to the SGM when the elasticity of substitution between natural gas and coal is increased to produce the same permit price and required emissions reduction, and the rate of autonomous energy efficiency improvement (AEEI) is increased from 0.90/yr to 0.96/yr. Table 4 below (which uses a 1990 stabilization target as the baseline because SGM results for this target have been published) illustrates the possible alignment of assumptions and results among these two models. Note that the SGM model assumes that a \$108/metric ton carbon tax would return 2010 greenhouse gas emissions to 1990 levels, largely by converting some coal-fired power plants to natural gas. The CRA model can reproduce this result using the higher elasticity and AEEI assumptions, but using our reference case assumptions, CRA concludes that the permit price would have to be closer to \$142/metric ton to achieve the same emissions reduction.

Using the \$142 carbon price, CRA estimates a direct cost of \$28 billion in 2010 and a total GDP loss of \$60 billion to purchase carbon permits equal to EIA projected greenhouse gas emissions in 2010. When the carbon price is reduced to \$109 by tripling the ease with which natural gas

could replace or substitute for coal in electric utilities and other boilers, the direct cost falls to \$20, identical to SGM's results. In this scenario, annual GDP losses would fall to \$52 billion.⁷

Table 4
Reconciling of CRA and SGM Results:
No Trading, 1990 Emissions Limit in 2010

	SGM	CRA Base	CRA Adjusted*
Carbon Tax (92 \$\$/Ton)	108	142	109
Emissions Reduction (Mm Metric Tons)	400	400	370
Direct Cost (92 \$Billion)	20	28	20
GDP Loss (92 \$Billion)	NA	60	52

*Adjusted for an increased elasticity of substitution between coal and gas and an increased autonomous energy efficiency improvement rate.

Source: CRA Multi-Region Trade Model and Edmonds, et al.

We find, like the Administration, that emissions trading would reduce the prices of permits and the economic impacts of emissions limits. However, the CRA model does not estimate cost savings or price reductions from emissions trading as large as those cited by Dr. Yellen. Table 5 below compares the percentage cost reductions estimated by the SGM and CRA models to those assumed by Dr. Yellen.

Table 5
Comparison of SGM, Administration, and CRA Savings from Emissions Trading

	SGM	Administration	CRA
Saving From Annex I Trading	40%	50%	29%
Additional Saving From Global Trading	25%	55%	40%
Total Saving From Global Trading	55%	77.5%	57%

Source: CRA Multi-Region Trade Model, Yellen testimony, and Edmonds, et al.

CRA and SGM are very close to each other in estimating the total cost savings of global trading, much closer than are the Administration and the SGM. CRA is somewhat less optimistic than SGM about cost savings from Annex I trading, but more optimistic than SGM about the savings from non-Annex I trading. We believe this is largely due to our assumptions about future

⁷ For consistency, the reconciliation of CRA and SGM uses a common scenario both models addressed in late 1997. The Administration analysis starts with the Kyoto agreement and requires a larger emissions reduction than estimated above because of updated carbon emissions projections by EIA and a more stringent emissions target. CRA's adjusted results include a somewhat lower required emissions reduction because changing other assumptions to match SGM affects the baseline as well as the policy case.

reforms in the Russian economy and our more complete treatment of international trade in energy and other goods that enables us to capture more of the competitive distortions caused by leaving developing countries out of the trading system. How the Administration found larger savings is less clear to us.

One of the most interesting conclusions of the SGM is that nearly all of the benefits of Annex I emissions trading disappear if Russia is not allowed to sell its excess emissions permits on the open market.⁸ As can be seen in Table 6 below, under Administration assumptions, Annex I trading with no "hot air" from Russia results in less than a 20% reduction in cost, whereas emissions trading provides a 40% reduction in direct cost if Russia is free to sell all of its excess permits. Our analysis supports this conclusion.

Table 6
SGM Estimates of Direct Costs as Percent of GDP in 2010
With and Without Russian Excess Permits

	No Trading	Annex I Trading
SGM Stabilization Russia Limited to Baseline Emissions	0.2%	0.18%
SGM Stabilization Russia Sells Excess Permits	-0.2%	-0.12%

Source: Edmonds, et al.

The Starting Point for Kyoto

CRA has replicated the Administration's starting point by adopting *arguendo* the fuel substitution elasticities and energy efficiencies needed to make the CRA results consistent with those of the Second Generation Model. Dr. Yellen's assumptions do lead logically to her conclusion, and with the same assumptions the CRA model gets very similar results for carbon prices and direct costs. Table 7 below shows that, with these assumptions, the CRA-estimated carbon permit price and direct cost for the case in which no international emissions trading is allowed are virtually identical to those implied by the Administration's testimony. CRA estimates a GDP loss, including both direct and indirect effects of the restriction on carbon emissions, that is about 60% larger than direct costs, or \$79 billion in 2010 under the Administration's assumptions.

⁸ Edmonds, et al.

Table 7

Comparison of CRA and Administration Starting Point for Kyoto

	CRA Adjusted*	Administration
Carbon Tax (97 \$/Metric Ton)	203	193
Emissions Reduction (MM Metric Ton)	530	550
Direct Cost (97 \$Billion)	53	53
GDP Loss (97 \$Billion)	79	Na

*Adjusted for an increased elasticity of substitution between coal and gas and an increased autonomous energy efficiency improvement rate. All prices are stated in 1997 dollars, which requires an inflation adjustment of 13% to prices reported by the CRA and SGM models in 1992 dollars. The required emissions reduction is smaller in the CRA Adjusted results because adopting the Administration's assumptions changes both the baseline and policy cases.

Source: CRA Multi-Region Trade Model and Yellen testimony.

CRA Results, Using Less Optimistic Trading Assumptions

Less optimistic assumptions about the speed with which utilities can replace coal with natural gas and on the progress of energy efficiency result in a significantly higher cost of reducing U.S. carbon emissions. Table 8 below illustrates the costs associated with other emissions trading scenarios. Table 8 reports results based on CRA's alternative assumptions about cost, namely, that utility replacement of existing coal with new natural gas units is limited during the next 10 years, and that energy efficiency improvement is no greater than that assumed by the Energy Information Administration.

Table 8

CRA Results for Limited Emissions Trading Under CRA Assumptions
(Change in GDP from Baseline and Carbon Price in 2010)

	GDP (%)	GDP (1997 \$)	Price (97\$/tonne)
No Trading	-1.27	\$129b	295
Annex I – No Excess Permit Sales	-1.09	\$111b	171
Annex – Unrestricted Trading	-0.91	\$92b	119
Global Trading	-0.54	\$55b	50

Source: CRA Multi-Region Trade Model.

No International Emissions Trading

If the nations that ratify the Kyoto Protocol are unable to agree on any trading system, CRA estimates that the cost of emissions reduction would rise to \$295 per metric ton and GDP losses would be \$128 billion in 2010 under realistic assumptions about utility costs and technology. This is the worst case, but given current divisions of opinion among the negotiating parties, it needs to be kept in mind as a reference.

Trading Among Annex I Countries

The Kyoto agreement provides explicitly for trading among Annex I countries.⁹ If the United States could achieve its goal of unrestricted trading among Annex I countries, the cost of Kyoto under realistic cost assumptions would be about 0.9% of GDP in 2010, or \$92 billion, with an international permit price of about \$120 per ton. This case includes, in the CRA analysis, about 160 million tons of excess permits offered for sale by Russia.

However, European countries and others have objected to Russian sales of permits in excess of projected baseline emissions, and have asked for "concrete limits" on the amount of a country's emissions obligation that can be satisfied through purchase of permits from other countries. A case that reflects the inability of the United States to overcome these objections fully is that of Annex I trading with "no hot air." This case is still optimistic, in that it places no limits on the amount of its obligation that the United States can satisfy through permit purchases internationally, but does assume that other countries succeed in their objective of limiting Russia's ability to sell permits above its projected baseline emissions. It does not include trading with developing countries, because such trading is not permitted under the Kyoto Protocol and is largely opposed by developing countries. Using the CRA model and assumptions, carbon permit prices would be about \$171 per metric ton with only Annex B trading and no sales of excess emissions permits from Russia. In that case, GDP losses would be 1.1% of GDP or about \$111 billion in 2010.

Global Trading

CRA concurs with the Administration that full global trading, if achievable, would produce a significant reduction in costs. Under CRA's cost assumptions, global trading would still imply a carbon price of about \$50 per ton and a GDP loss of over 0.5% in 2010, or \$55 billion. This is a cost reduction of about 57% from the cost of Kyoto with no international emissions trading.

⁹ Table 8 assumes full Annex I trading but does not include benefits of excluding the EU from bidding for Russian emissions permits. Additional details on this alternate scenario will be available in a forthcoming CRA report, but the disadvantage to the EU of such a policy argues against its acceptance of the rest of the Administration's proposal unless the EU also could share their benefits.

Conclusions

Analysis of Dr Yellen's March 4, 1998 testimony before the Senate Foreign Relations Committee and the modelling efforts discussed above suggest two broad conclusions:

- *The United States would have to purchase a large share of its emissions reduction obligation to achieve the savings estimated by the Administration.* With the permit prices cited by the Administration for full global trading, the U.S. would only lower domestic emissions by some 65 to 125 million metric tons in 2010. This means that the United States would need to purchase 82% to 88% of its 550 million metric ton emissions reduction obligation from other countries – a figure well above that the EU and other countries have indicated they find acceptable.
- *Fewer opportunities to purchase emissions credits would mean higher costs.* U.S. costs could reach \$170 per ton with limited emissions trading – or more than 10 times what the Administration estimates. Under alternative assumptions about ease of gas for coal substitution and energy efficiency improvement and a scenario in which only restricted Annex I trading is permitted, the Kyoto agreement could cost the U.S. economy 1.1% of GDP in 2010 – over \$110 billion – while the permit price would be over \$170 per ton.

Given her assumptions, Dr. Yellen's analysis is internally consistent and compatible with mainstream economic analysis. However, her cost estimates include only direct costs, not the full impacts to the economy of implementing the Kyoto Protocol, and very optimistic assumptions are made about the economy's ability to reduce emissions at low cost. Further, Dr. Yellen has assumed worldwide permit trading and very extensive purchases of these permits by the U.S., whereas the Kyoto Protocol includes only limited trading possibilities and may preclude such extensive U.S. purchases. If these assumptions fail to materialize, the Administration's estimates of permit prices and GDP costs will need to be adjusted upwards by a factor of ten or more.