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cars that meet tough vehicle emissions standards. ... A key drawback to a hydrogen-powered car is the lack of a distribution system for hydrogen gas to power the vehicles," according to Takanori Minami, general manager of the company's technical research center in Hiroshima, Japan. "Hydrogen gas currently costs about $2 per cubic liter, meaning it would cost about $74 to fill the HR-X's tank. But Minami said cheaper sources of hydrogen gas could come as a byproduct of steelmaking" (Rob Wells, AP/ALBANY TIMES UNION, 4/17).

*9 PENCILS: RECYCLED NEWSPAPERS FIND A USE

Faber-Castell this week unveiled a pencil made of recycled newspaper and cardboard fibers. The Parsippany, NJ, company says the "American EcoWriter" is the first major development in pencil composition since erasers were introduced at the turn of the century. Chris Wiedenmeyer, chairman of the board of the company: "There is a growing demand for recycled products. We're trying to stay ahead of the curve." About 15 percent of the 1 billion pencils sold each year by the company will use the recycled product. Wiedenmeyer says the company will benefit both from the consumer demand for the recycled product and in savings as the price of wood goes up. He says Faber-Castell hopes to eventually make all its pencils from the product, which right now costs slightly more than wood. Ronald Mersky, an associate professor of civil engineering at Widener University in Chester, PA, says the 75 tons of waste the recycled pencils will save each year is less than what a big city generates in one day. Mersky: "It's not to say it's not a productive contribution" (AP/NASHVILLE BANNER, 4/20).

*10 ALUMINUM: INDUSTRY MAY CONTRIBUTE TO GREENHOUSE EFFECT

file w/ - aluminum in climate change

"Canada's aluminum makers have generally basked in a favorable environmental light," reports Martin Mittelstaedt in the Toronto GLOBE AND MAIL. "This is an industry, after all, that has promoted metal recycling. As well, most aluminum in Canada is produced by hydroelectric power, not petroleum-based fuels; thus, it has been viewed as a minor contributor to the greenhouse effect. However, in their first assessment of the aluminum-industry's emissions and global warming, [Canadian] environmental officials have found that two little-studied waste gases emitted in aluminum production -- tetrafluoromethane and hexafluorethane -- are among the most important greenhouse gases created by human activity." He reports that their effect may be thousands of times that of carbon dioxide, and makes the aluminum industry second only to producers of CFCs in emitting greenhouse gas, producing the equivalent of 6 percent of Canada's entire output of carbon dioxide, according to Environment Minister Jean Charest in a confidential document to Jim Fulton, a member of

M E M O R A N D U M

DATE: January 13, 1992

TO: Senator Gore

FROM: Mike Nelson

SUBJECT: The Aluminum industry and global warming

Before the end of the month, I expect there to be some press stories about how the aluminum industry is contributing to global warming. Apparently, the aluminum industry recently discovered that the aluminum smelting process produces significant quantities of carbon tetrafluoride (CF-4) and C2F6. These are incredibly stable compounds belonging to a class of compounds called poly-fluorinated compounds (PFCs). These are NOT ozone-depleting chemicals, but they are powerful greenhouse gases. Alcoa and other aluminum companies are eager to make sure you are fully briefed on this new finding and would be happy to brief you if you wish.

The key points:

The atmospheric concentration of CF4 is about 70 parts per trillion.

CF4 and C2F6 have very long lifetimes--about 10,000 to 20,000 years.

Aluminum smelting is the only significant source of CF4. About 1 pound of CF4 is produced for each ton of aluminum. U.S. production of aluminum: about 4 million metric tons. Global production: about 17 million metric tons.

other sources C2F6?

A molecule of CF4 absorbs about 2,000 times as much infrared radiation as a molecule of CO2. However, it is much less abundant. Although the calculations are still preliminary, it is clear that CF4 and C2F6 are responsible for less than one-quarter of one percent (or 1/400) of present-day global warming.

? C2F6 too?

Because of its long lifetime, CF4 will continue to accumulate in the atmosphere. Consequently, the aluminum industry is eager to reduce emissions.

C2F6 too?

By altering the smelting process, it is possible to minimize the amount of CF4 produced. The industry is investigating how best to do this.

Would you like a briefing on this issue?

file Aluminum [illegible]
Climate

PROFESSOR DEAN ABRAHAMSON

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January 30, 1992

Anthony Socci
Commerce Committee
U.S. Senate
427 Hart Building
Washington, DC 20510

Dear Dr. Socci:

I enjoyed our conversation, and look forward to following these matters as they evolve.

Several things are enclosed:

AMBIO Manuscript

This is in the form of a commentary on an article by Henning Rodhe, <u>et al.</u>, published in **Ambio** last spring. There were actually four companion articles, summarizing the Swedish greenhouse gas emission budgets.

The manuscript was sent for technical review, accepted for publication, and the enclosed is the "final" text. It will be published in March. Feel free to circulate it, with the cover page indicating that publication is forthcoming.

NATURE Letter

This is the briefest of submissions entertained by **Nature.** I sent it off in late-December and have as yet received no response from the editors.

If you circulate it, make it clear that it has not been reviewed or accepted (or rejected) by the editors.

Reprints of newsletters

The current issues of **Energy, Economics and Climate Change** and of **Global Environmental Change Report** have blurbs about this work. These are published (were distributed last week) and so can be circulated at will.

Iceland, Aluminum, and the Greenhouse Effect

This was published, in Icelandic, in November [the Icelandic citation is noted in the box on the cover page].

It illustrates the situation for countries which have made a commitment to reduction in their emissions of greenhouse gases, and are contemplating expansions of their primary aluminum industries. The Icelandic case is extreme because of circumstances peculiar to Iceland.

It was written for popular consumption and published in Iceland's largest daily newspaper. [I can send the Icelandic version if you want.] It lays out the policy box which Iceland faces in encouraging a new smelter while at the same time meeting their greenhouse gas stabilization commitment.

Circulate it at will.

Misc. Tables

Note that some of these tables are from published literature and some are **DRAFT** and the numbers not verified. Please do not cite or circulate the latter.

Some of this stuff was done for the papers above, some as part of a longer piece that I'm working on for **Climatic Change** or a similar journal. I don't expect to have a manuscript ready for submission for a few weeks.

I would prefer that this be given very limited, if any, distribution.

Please let me know if there is any way in which I can be of assistance to you. Also, I have copies of all source materials cited in the above and, if you can't find them locally, I can have copies made and sent to you. [Please bear in mind, however, that I have essentially no secretarial support and anything that I copy, I copy myself, etc.]

Finally, I often work at home and do not hesitate calling there if you can't reach me at the office. My home phone is (612) 623-9449.

Sincerely yours,

Dean Abrahamson

enclosures (6)

ICELAND, ALUMINUM, AND THE GREENHOUSE EFFECT

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22 Nov 1991 Part 1, 26 Nov 91 Part 2

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file: smelter.pap

ICELAND, ALUMINUM, AND THE GREENHOUSE EFFECT

Dean Abrahamson and Valdimar K. Jónsson

THE CONTEXT

Human activities are releasing pollutants into the atmosphere which are resulting in global heating, climatic change, and destruction of the stratospheric ozone layer. The consequences of these disturbances are regarded as potentially catastrophic by national and international authorities and agencies.

The international community has formulated, and most industrialized countries have signed, the Montreal Protocol on Substances that Deplete the Ozone layer, making a commitment to phase out the use of these substances, most of which are chlorofluorocarbons (CFCs), within about a decade. Iceland is a signatory to the Montreal Protocol.

An Ozone Committee, under the jurisdiction of the Icelandic Ministry of Industry, has summarized uses of CFCs and other ozone-depleting substances. The Ministries of Industry and Ministry of Health and Social Security were charged with meeting commitments under the Montreal Protocol after ratification by the parliament in 1989. The first action taken was a ban on ozone-depleting substances in spray cans effective 1 June 1990. The Ministry of Environment is now preparing a program to phase out the use of CFCs, particularly in fish and other food processing industries where they are used as the working fluid in refrigerators and freezers.

There are similar international and national efforts underway to control emissions of greenhouse gases — the pollutants which are responsible for global warming. Negotiations are in progress for an international greenhouse gas convention along with other initiatives associated with the United Nations Conference on Environment and Development (UNCED) to be held in Rio de Janeiro in June 1992.[1]

Iceland — together with the other European Free Trade Association (EFTA) and European Community (EC) countries, Australia, Canada, Japan, and New Zealand — agreed, in October 1990, to stabilize carbon dioxide emissions at not greater than the 1990 levels by the year 2000 as a first step toward making the reductions necessary to slow the rate of global climate change.[2] This agreement is formally concerned with carbon dioxide, but is widely interpreted as applying to all greenhouse gases.

A Carbon Dioxide Committee was established under the jurisdiction of the Ministry of Environment following the November 1990 EFTA agreement to stabilize emissions. The Committee is developing an inventory of emissions and proposals for achieving their reduction.[3]

Initial international efforts to limit climatic change caused by man-made increases to the greenhouse effect are focused primarily on carbon dioxide released from the burning of fossil fuels — coal, oil, and natural gas — and from deforestation and other land-use changes which result in loss of vegetation and soil carbon. This makes sense. Carbon dioxide produced from fossil fuel burning produces 55% of the increases to the greenhouse effect by human activities.[4] Reducing fossil fuel use will also result in reductions of methane and nitrous oxide emissions which, together, are responsible for 21% of global heating.[5]

The chlorofluorocarbons (CFCs) are the remaining class of important greenhouse gases, in addition to being the most important ozone-depleting substances. They are responsible for 24% of the global greenhouse effect — 17% from CFC-11 and CFC-12, the balance from CFC-113, HCFC-22, CFC-14, CFC-116, and several others. Additionally, many of the substitutes for ozone-destroying CFCs are powerful greenhouse gases and efforts to comply with the Montreal Protocol will not necessarily reduce greenhouse heating from CFCs.

It is customary to express the global heating from all greenhouse gases in terms of that from an equivalent amount of carbon dioxide computed by using an index defined as the Global Warming Potential (GWP). For example, a kilogram of methane produces the same amount of global warming over a 100-year period as do 21 kilograms of carbon dioxide, hence methane has a GWP_{100} of 21.

THE IMPORTANCE OF ALUMINUM SMELTING

Aluminum smelting produces greenhouse gas emissions in three ways:

- Energy used for producing electricity, carbon electrodes, and other steps in the aluminum production process releases carbon dioxide (CO_2), carbon monoxide (CO), methane (CH_4), and nitrous oxide (N_2O), each contributing to global heating;

- Reducing alumina to aluminum metal produces additional CO_2 ;

- CFC-14 and CFC-116 are produced from reactions with cryolite and alumina as by-products of aluminum smelting;[6,7,8]

Electricity is the largest energy input into aluminum smelting, the average smelter consuming 16,800 kilowatt-hours of electricity for each 1000 kilograms (metric ton) of aluminum produced (kWh/tAl). Electricity produced from hydropower and geothermal power produces very small greenhouse gas emissions, electricity from coal-fired plants produces large emissions.

Alumina reduction produces about 1.76 tons of carbon dioxide per ton of aluminum metal, in addition to that which may result from electricity production.[9]

CFC-14 and CFC-116 are extraordinarily powerful greenhouse gases, having 100-year global warming potentials of 10,900 and 11,500 respectively. Aluminum smelting produces (1.6 ± 0.2) kg-CFC-14 per ton of aluminum, and (0.2 ± 0.02) kg of CFC-116 per ton of aluminum.[10] CFC-14 and CFC-116 releases, therefore, are equivalent to emissions of 19.74 tons of CO_2 per ton of aluminum using a 100-year Global Warming Potential.[11]

Taken together, the emissions from aluminum production, in a smelter which uses electricity produced from hydropower, have a greenhouse contribution equal to that from emissions of 21.5 tons of CO_2 per ton of aluminum.

ICELANDIC GREENHOUSE GAS EMISSIONS

In 1990

Icelandic greenhouse gas emissions include significant amounts of carbon dioxide, methane, nitrous oxide, CFCs used as refrigerants and foam-blowing agents, and CFCs produced as a by-product of aluminum smelting, Table 1.

Ninety percent of Icelandic CO_2 emissions are from the use of petroleum products and coal, 70% of which are petroleum products used for transport,[12] Table 2.

By the Year 2000

Fossil fuel consumption decreased following programs to reduce consumption after the oil shocks of the 1970s, but has been increasing since 1983 at the rate of about 5% per year, with petroleum use in the domestic transportation sector increasing at about 6% per year.[13] If petroleum consumption were to increasing at 5% per year, CO_2 emissions from petroleum consumption would increase from the 1990 level of about 2,400 thousand tons to about 3,900 thousand tons by the year 2000. Carbon dioxide emissions from fossil fuel use could, therefore, increase by about 1,500 thousand tons per year if the current trends in petroleum consumption were to continue to the year 2000. If petroleum consumption growth rates were reduced to 2% per year, carbon dioxide emissions would increase by 500 thousand tons per year.

An increase in fossil fuel use would also result in increased emissions of methane and nitrous oxide. The extent to which other sources of methane change will be largely dependent on changes in the numbers of domestic animals and the way in which land-fills are operated. Nitrous oxide emissions would also increase were more fertilizer used, for example, for an expanded program of revegetation and reforestation. Changes in emissions of methane and nitrous oxide will, however, be small compared with those of carbon dioxide and the CFCs.

Iceland has been shifting to CFCs for refrigerators, freezers, plastic foams, and other conventional uses, to chemicals which are less damaging to the ozone layer. This shift has not yet, however, reduced the greenhouse contribution from CFCs used for these purposes.[14] It seems likely, however, that a reduction will be achieved before the year 2000.

A second aluminum smelter of 210,000 tons per year capacity, is being proposed. This smelter would increase aluminum production capacity from the present 90,000 tons per year to 300,000 tons per year. Such a new smelter would increase carbon dioxide emissions by about 370 thousand tons per year.[15] If the conventional Hall and Héroult smelting process were used in a new smelter, emissions of CFC-14 and CFC-116 would increase the greenhouse contribution equivalent to emissions of an additional 4,100 thousand tons of CO_2 per year.[16]

Stabilization of Emissions in 2000 at 1990 Levels

The extent to which greenhouse gas emissions need to be controlled by the year 2000 depends on several factors, the most important of which are fossil fuel consumption growth rates, the proposed new aluminum smelter, and the interpretation of the EFTA stabilization commitment.

If The Stabilization Commitment Applies only to CO_2

A new 210,000 ton per year aluminum smelter in operation by the year 2000 would cause CO_2 emissions to increase by 370 thousand tons per year. Petroleum consumption would result in increases in CO_2 emissions by zero, 500, or 1500 thousand tons per year with oil consumption growth rates of zero, 2, and 5 percent per year respectively.

If The Stabilization Commitment Applies to all Greenhouse Gases

If a new 210,000 ton per year aluminum smelter, using the conventional Hall and Héroult process, were in operation by the year 2000, CFC-14 and CFC-116 emissions would further increase, making a greenhouse contribution equivalent to a 4100 thousand tons of CO_2(equivalent). The total increase would then be 4470 thousand tons CO_2(equivalent) from the smelter plus the contribution resulting from changes in oil consumption.

OPTIONS FOR REDUCING EMISSIONS

There are several approaches available to reduce Icelandic greenhouse gas emissions prior to the year 2000, including:

- Adding pollution control devices to remove CFC-14 and CFC-116 from aluminum smelter exhaust gases;

- Switching to a aluminum reduction process which produces neither CFC-14 nor CFC-116 as does the conventional Hall and Héroult process;

- Switching from CFCs used at present for conventional purposes to compounds which have little or no greenhouse effect;

- Reducing the use of fossil fuels;

- Undertaking a large reforestation program which would remove carbon dioxide from the atmosphere and hence compensate for the increased emissions which could occur before the year 2000.

Removing CFC-14 and CFC-116

Pollution control devices currently used in aluminum smelters do not remove CFC-14 or CFC-116.[17] The development and use of techniques for CFC-14 and CFC-116 removal from smelter exhaust air would reduce, perhaps eliminate, this source of greenhouse gas pollution. Were this done for both the exiting and the proposed new aluminum smelters, greenhouse gas emissions would be reduced below 1990 levels by the equivalent of about 1000 thousand tons of CO_2. This would permit petroleum consumption to increase by about 3.5% per year until the year 2000,[18] but would require no further increases in fossil fuel use after that time unless further measures were taken to reduce net CO_2 emissions.

Using a Different Smelting Process

Several alternatives to the conventional Hall and Héroult aluminum reduction processes are known. For example, the Alcoa process avoids productions of CFC-14 and CFC-116, and uses less electricity.[19] Recognition of the environmental costs of the greenhouse effect caused by the conventional smelting process, perhaps through a tax on greenhouse gas emissions,[20] is likely in the near future. This will force reexamination of the Alcoa, and other, alternative smelting processes.

Were the new smelter to use the Alcoa process, its CO_2 emissions would be about the same as with a conventional smelter, but there would be no emissions of CFC-14 or CFC-116. An Alcoa-process smelter could, however, produce another greenhouse gas, carbontetrachloride (CCl_4), which would either have to be removed from the smelter exhaust air or compensated for by reductions in other greenhouse gas emissions.

Replacing CFCs Used As Refrigerants

The greenhouse effect implications of releases of CFCs used as refrigerants, foam blowing agents, and a variety of other purposes are well recognized. Work is under way in several countries to develop means to accomplish the same ends without emissions of chemicals that deplete the ozone layer or add to greenhouse heating.

1990 emissions from these CFCs, and a small amount from a related class of pollutants known as halons, were equivalent to emissions of 890 thousand tons of CO_2. Replacement of all of these compounds by those which were not greenhouse gases would, therefore, compensate for the increased CO_2 emissions from a new smelter and permit petroleum consumption to increase by about 2% per year until the year 2000, with no growth thereafter. The greenhouse contribution from CFC-14 and CFC-116 emissions would, however, remain unresolved.

Reducing Use of Fossil Fuels

Fossil fuels could be replaced with electricity, hydrogen, or alcohol produced from Icelandic solar, hydro, and geothermal energy. To do so would require at least a decade, perhaps longer, and the economic implications of such a switch have not yet been investigated.

If the EFTA commitment is interpreted as applying only to carbon dioxide, petroleum use would have to be reduced between 1990 and 2000 by about 15% of 1990 levels to compensate for emissions from the new smelter. Replacing this oil by hydrogen produced from Icelandic hydropower would require about 2.35 TWh(e).[21] This is 53% of 1990 electricity production, almost exactly the amount now used for the aluminum and the ferro-silicon smelters. Additional hydrogen would have to be produced to supply any increased need for transportation fuels.

If, on the other hand, the EFTA commitment is interpreted as applying to all greenhouse gas emissions, even replacing all oil with hydrogen would not be sufficient to stabilize emissions. Further, this replacement would require the annual consumption of 15.2 TWh(e), nearly three and a half times 1990 electricity production. Offsetting the total greenhouse contribution from the new smelter would require about 28 TWh(e), or six times the amount of electricity used for all purposes in 1990.

Reforestation To Remove Carbon Dioxide from the Atmosphere

Just as deforestation adds carbon dioxide to the atmosphere, growing new trees removes atmospheric carbon dioxide. This is because all of the carbon in living things is taken from the atmosphere through photosynthesis by green plants. Trees are, on average, about 45% carbon and, as they grow, become storage sites for carbon dioxide that was once in the atmosphere. It must be realized, however, that new forests remove CO_2 from the atmosphere only until they reach maturity — in the Icelandic case about 40 to 60 years — and would then release as much carbon dioxide to the atmosphere as they remove from it.

Iceland was heavily wooded at the time of the settlement, but has now been largely deforested. The forests further suffered from the harsh climate during the 1400s and 1500s and from volcanic eruptions. Only isolated remnants of the old forests remain, but estimates are that 11,000 square kilometers (km^2) of Icelandic land is suitable for growing trees under present climatic conditions.[22]

If the EFTA agreement is interpreted as applying only to CO_2, reforestation of approximately 1,070 km^2 would be necessary to remove the 370 thousand tons of CO_2 released by the new smelter.[23] At the other extreme, namely interpretation of the EFTA agreement as being applicable to all greenhouse gas emissions, reforestation of the entire 11,000 km^2 regarded as being capable of growing trees would remove only 85% of the emissions from the new smelter.

CONCLUSION

The Icelandic government, together with those of the other EFTA countries, the EC countries, New Zealand, Japan, Australia, and Canada, has made a commitment to stabilize greenhouse gas emissions at not more than the 1990 levels by the year 2000. The government is also on the verge of making a commitment to a second aluminum smelter. Further, carbon dioxide emissions have been increasing rapidly since 1983 because of increasing fossil fuel consumption — largely by the transportation sector.

Various combinations of actions are open to compensate for the potentially increased greenhouse gas emissions by the year 2000. Which of these actions are necessary depend critically upon three factors: the interpretation as to whether the EFTA agreement shall apply to all greenhouse gas emissions or only to carbon dioxide; the growth (or decline) in greenhouse gas emissions from oil consumption between now and the year 2000; and the choice of technology to be employed were a second smelter built and operated.

Development and use of means to remove CFC-14 and CFC-116 from the existing and the proposed new aluminum smelter would reduce emissions sufficiently to compensate for the CO_2 emissions from the new smelter and would yet permit oil consumption to increase by about 3.5% per year until the year 2000. Greenhouse gas emissions from the energy sector would, however, have to be stabilized at year 2000 levels.

Building a new smelter which uses one of the alternatives to the conventional Hall and Héroult smelting process, for example, that developed by Alcoa, would have a similar effect as would removing CFC-14 and CFC-116 from smelter exhaust air, assuming that no other greenhouse gases, for example carbontetrachloride, were released.

Replacing all CFCs used as refrigerants, foam blowing, and other purposes with technology producing no greenhouse heating would compensate for increased CO_2 emissions for a new smelter and would permit petroleum consumption to increase by about 2% per year until the year 2000, and its stabilization thereafter. However, the contribution to greenhouse heating from increased CFC-14 and CFC-116 emissions would yet remain.

Petroleum could be replaced by hydrogen produced from Icelandic hydropower. Compensation for the increased CO_2 emissions from a new smelter would require an increase in electricity production by 53% plus that necessary to supply any increased demand for transportation fuels.

Finally, reforestation of about 1,070 km^2 would compensate for the increased CO_2 emissions from a new 210,000 ton per year aluminum smelter. This is 76% of the 1,400 km^2 now under cultivation for agricultural purposes. A substantially larger area would have to be reforested to offset any increased use of fossil fuels.

It appears that some combination of the above measures will likely be required if emissions are to be stabilized by the year 2000.

Table 1 Icelandic greenhouse gas emissions, by greenhouse gas, in percent of their total greenhouse contribution using 100-year Global Warming Potential.

Greenhouse Gas	Percent
Carbon Dioxide	49.4
CFCs — aluminum smelting	23.0
CFCs, other & halons	14.9
Methane	7.4
Nitrous Oxide	5.3

Table 2 Carbon dioxide emissions from Icelandic economic activities, 1990, in thousands of tons.

Activity	1000 Tons CO_2	Percent
Fishing vessels	734	25
Motor vehicles	553	19
Other ships	502	17
Icelandic aircraft	333	11
Coal and coke	249	8
Industrial petroleum	182	6
Carbon electrodes	150	5
Other petroleum	63	2
Res. & comm. oil	60	2
Geothermal power	52	2
Cement ($CaCO_3$)	51	2
Imported wood	31	1
Electricity (oil)	5	< 1
Fertilizer ($CaCO_3$)	4	< 1
TOTAL	2968	100

REFERENCES AND NOTES

1. The Rio conference will not have the authority to accept the terms of the proposed convention, but it will be able to give its seal of approval so that the convention can be presented for signature at the autumn 1992 session of the United Nations General Assembly. See: *International Environment Reporter* (10 April 1991).

2. Agreement of joint meeting of EC and EFTA environment ministers, Geneva, 5 November 1990. The Icelandic commitment was reinforced by the ministerial declaration of the 2nd World Climate Conference, Geneva, 7-9 November 1990 where the EC and EFTA countries were joined by New Zealand, Japan, Australia, and Canada.

3. Ottósson, Jón Gunnar, Bragi Árnason, Flosi Hrafn Sigurđsson, Guđjón Jónsson, Jón Ólafsson, Ólafur Pétursson, Valdimar K. Jónsson, Sigurbjörg Sæmundsdo´ttir, and Ágúst S. Sigurđsson, *Útstreymi koltvíildis og brennisteinstvíildis á Íslandi árið 1990,* Draft report of the Carbon Dioxide Committee (19 June 1991).

4. The natural greenhouse effect causes a global warming of about 33 degrees Celsius. Were there not this background greenhouse effect, the Earth would be below freezing. Throughout this article, *greenhouse effect* refers to *additions to the natural background greenhouse effect* because of releases of greenhouse gases from human activities.

5. Intergovernmental Panel on Climate Change (IPCC), *IPCC First Assessment Report*, World Meteorological Organization and United Nations Environment Programme (August 1990).

6. Between 20 and 30 kg of compounds containing fluorine are produced as by-products of the Hall and Héroult aluminum smelting process. Virtually all aluminum smelting is done with this process. Included among these fluoride compounds are CF_4, called CFC-14, and C_2F_6, called CFC-116. CFC-14 and CFC-116 do not have known adverse effects on human health nor do they destroy stratospheric ozone. But, they are powerful greenhouse gases. See, for example: Fabian, P., R. Borchers, Krüger, B.C. & Lal, S., *Journal of Geophysical Research*, **92**, 9831-9835 (1987).

7. Measurements in the plumes of aluminum smelters have shown that aluminum smelting is almost certainly the only anthropogenic source of CFC-14 and CFC-116. See: Penkett, S.A., Prosser, J.D., Rasmussen, R.A., and Khalil, M.A.K., "Atmospheric Measurements of CF_4 and other Fluorocarbons Containing the CF_3 Grouping," *Journal Of Geophysical Research*, **86**, 5172-5178 (1981).

8. A recent review of the greenhouse effect being caused by the CFCs is: Hansen, J., Lacis, A. & Prather, M., *Journal of Geophysical Research*, **94**, 16417-16421 (1989).

9. The theoretical minimum is 1.221 tons of CO_2 per ton of aluminum. In practice, however, 0.45 $\pm$ 0.05 tons of carbon are consumed at the smelter anode, and 0.03 $\pm$ 0.01 tons of carbon are consumed at the cathode for each ton of aluminum metal produced. Total CO_2 produced by alumina reduction is hence about 1.76 tons CO_2 per ton of aluminum. See: Elvers, B. [ed], *Ullman's Encyclopedia of Industrial Chemistry*, VCH, Weinheim (1985).

10. Full technical details of the relationship between aluminum smelting and CFC-14 and CFC-116 emissions are summarized in: Abrahamson, D., "CFC-14 and CFC-116 Emission Coefficients for Aluminum Smelting," submitted to *Nature* (October 1991).

11. CFC-14 and CFC-116 emissions would be equivalent to much larger CO_2 emissions if a longer GWP integration time were used. As CFC-14 and CFC-116 cause essentially permanent climatic change — they have an atmospheric residence time of greater than 10,000 years, much longer than the other known greenhouse gases — a longer GWP integration time might be appropriate.

12. Abrahamson, D., Jónsson, V.K. & Sólnes, J., "Iceland and Climatic Change," *Proceedings of the First Nordic Inter-Disciplinary Research Conference on the Greenhouse Effect*, Copenhagen, In press (Sept. 1991).

13. National accounts of fossil fuel consumption are reported by international agencies. Interpretation of these data must be done with care, particularly as different agencies handle fuels used for international transportation (bunker fuels) differently. The International Energy Agency data set reports bunker fuels separately from those consumed within a country. See, for example: International Energy Agency, *Energy Balances of OECD Countries*, OECD, Paris (1991).

14. These data are detailed in Abrahamson, *et al., op cit.*

15. 210,000 tons-aluminum/year • 1.76 tons-CO_2/ton-aluminum = 369,600 tons-CO_2/year.

16. 210,000 ton-aluminum/year • 19.74 tons-CO_2(equivalent)/ton-aluminum = 4,145,000 tons-CO_2(equivalent)/year.

17. Fabian, P., *et al., op cit.*

18. 1990 emissions of CFC-14 and CFC-116 from the existing smelter were equivalent to 376 thousand tons of carbon or 1379 tons of CO_2. Removing CFC-14 and CFC-116 from the existing smelter exhaust would therefore compensate for the 370 thousand tons of CO_2 from the new smelter plus an additional 1000 thousand tons of CO_2. This would permit increasing the emissions from petroleum use from the 1990 level of about 2400 to 3400 thousand tons of CO_2. This, in turn, would permit an average growth rate of oil consumption by 3.5% per year between 1990 and 2000.

19. The Alcoa process first reacts alumina with chlorine and carbon producing aluminum chloride which is then dissociated by electrolysis to aluminum metal and chlorine. $2\ Al_2O_3 + 6\ Cl + 3\ C \rightarrow 4\ AlCl_3 + 3\ CO_2 \rightarrow 4\ Al + 6\ Cl_2 + 3\ CO_2$. It is a closed process. See: Elvers, *op cit.*

20. The European Community has recently proposed a $10 per barrel tax on oi' as part of its efforts to reduce greenhouse gas emissions. This translates t a tax of $80 per ton of carbon. If greenhouse gas emissions on aluminum production were taxed proportionally to the proposed EC tax on oil, the tax would be about $450 per ton of aluminum metal smelted with electricity produced from hydropower, but over $900 per ton if the electricity were produced from coal. The present price of aluminum metal is about $1,150 per ton. See: Montgomery, P.L., "Heavy Energy Tax is Proposed to Curb Emissions in Europe," *New York Times* (26 September 1991); Aluminum price from *New York Times* (27 September 1991).

21. Petroleum use would have to be reduced sufficiently to reduce CO_2 emissions by the 370 thousand tons from a new 210,000 ton per year smelter. This is equivalent to reducing oil consumption by 117 thousand tons per year. 50 thousand tons of oil can be replaced by hydrogen produced from 1 terawatt-hour of electricity (TWh(e) = 10^{12} watt-hour(e)), so replacing 117 thousand tons of oil would require 2.35 TWh(e).

22. Páll Bergþórsson, Hólmgeir Björnsson, Ólafur Dýrmundsson, Bjarni Guðmundsson, Áslaug Helgadóttir, and Jón Viðar Jónmundsson, "The Effect of Climatic Variations on Agriculture in Iceland," in M.L. Perry, et al. [eds], *The Impact of Climatic Variations on Agriculture. Volume 1. Assessments in Cool Temperate and Cold Regions*, Reidel, Dordrecht, The Netherlands: 1987.

23. It is estimated that new forests in Iceland would store 0.94 tons of carbon per hectare per year from the time the forests were planted until they reached maturity, perhaps 40 to 60 years. Therefore, removing 370,000 tons of CO_2 per year would require: [(370,000 tons CO_2/year) · (0.272 tons carbon/ton CO_2)] / [0.94 tons carbon/hectare-year] = 107,350 hectares = 1,074 km^2.

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MISCELLANEOUS MATERIALS ON CF_4 and C_2F_6

1] Table 1 from Hansen, J.,Hansen, J., Lacis, A. & Prather, M, *Journal of Geophysical Research* 94, 16417-16421 (1989).

2] Note on the reactions producing CF_4 and C_2F_6 in primary aluminum smelters which use he Hall-Héroult process [used by all commercial smelters.]

3] **DRAFT** table of greenhouse gas releases from primary aluminum smelters from several countries.

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4] **DRAFT** table showing greenhouse gas releases from primary aluminum production as a function of the primary energy source used to produce the electricity.

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TABLE 1. Global Mean Radiative Forcing of the Climate System (ΔT_o) due to Estimated Changes of Several Trace Gases During the 1980's.*

	ΔT_o, °C	Growth Rate, %/yr	Estimated Abundance, pptv 1980	Estimated Abundance, pptv 1990	Band Strength, cm^{-2} atm^{-1} stp	Remarks
CCl_2F_2 (CFC-12)	0.0143	4.6	297	468	3642	a, S
CCl_3F (CFC-11)	0.0067	4.7	173	275	2782	a, S
CCl_2FCClF_2 (CFC-113)	0.0057	13.3	20	70	5315	a, R
$CHClF_2$ (CFC-22)	0.0034	8.2	50	110	2627	a, F
CF_4 (CFC-14)	0.0009	2.5	70	90	4640	b, S
CCl_4	0.0007	1.5	100	115	1437	a, P
$CClF_2CClF_2$ (CFC-114)	0.0004	5.8	4	7	6570	a, R
CF_3Cl (CFC-13)	0.0004	4.7	7	11	4452	b, S
CF_3CF_2Cl (CFC-115)	0.0003	9.0	2	5		a, X
CH_3CCl_3	0.0002	4.4	110	170		a, Y
CH_2Cl_2	0.0002	3.9	30	44	583	b, P
CH_2ClCH_2Cl	0.0002	2.4	30	38		b, Z
CF_3Br	0.0002	18.2	0.6	3.2	4144	a, P
C_2F_6 (CFC-116)	0.0001	3.2	4	5.5	4861	b, P
$CHCl_3$	0.0001	2.2	10	12.5	1149	b, P
Sum	0.0338					

*CFC growth rates are based on (a) data of the International Ozone Trends Panel as summarized by *Watson et al.* [1988] and (b) on *Ramanathan et al.* [1985] estimates. Abundances are in parts per trillion by volume. Absorption data used to compute ΔT_o were obtained from the following sources or assumptions indicated under the Remarks column: S [*Smith et al.*, 1985], R [*Rogers and Stephens*, 1988], F (D. Fisher, private communication, 1989), P [*Pugh and Rao*, 1976], X (assumed to absorb like CFC-113), Y (scaled from *Hummel and Reck* [1981]), Z (assumed to absorb like CH_3CCl_3).

Sources of CF_4 and C_2F_6

usual textbook sources of CF_4 & C_2F_6:

1.16 volts $2\ Al_2O_3 + C \leftrightarrow 4\ Al + 3\ CO_2$

1.80 volts $2\ Na_3AlF_6 + Al_2O_3 + 3\ C \leftrightarrow 3COF_2 + 6NaF + 4\ Al$
COF_2 being unstable and producing CO_2 and CF_4

2.55 volts $4\ Na_3AlF_6 + 3\ C \leftrightarrow 4\ Al + 12\ NaF + 3\ CF_4$

Usual voltage across a cell is about 4 volts, across electrolyte, 1.6 volts.
During Anode Effect, 25-40 volts across cell.

2

3

Table 2 Greenhouse contribution in tons equivalent carbon dioxide emissions per ton of aluminum metal, $tCO_2[eq]/tAl$, from primary aluminum production using 100-year global warming potential. A smelter consuming 16.8 MWh(e) per ton of aluminum metal is assumed.

Primary Energy and Power Plant	Smelting: Elect-ricity	Smelting: Alumina Reduct-ion	Smelting: CFC-14 & -116	Smelting: Total	Bauxite and Alumina	Total Aluminum
Coal						
Conventional	21.6	1.76	19.74	43.3	2.1	45.4
Best Available	17.2	1.76	19.74	38.7	2.1	40.8
Oil						
Conventional	13.6	1.76	19.74	35.1	2.1	37.2
Best Available	10.5	1.76	19.74	32.0	2.1	34.1
Natural Gas						
Conventional	9.9	1.76	19.74	31.4	2.1	33.5
Best Available	7.4	1.76	19.74	28.9	2.1	31.0
Nuclear	3.0	1.76	19.74	24.5	2.1	26.6
Hydropower	-0-	1.76	19.74	21.5	2.1	23.6

4

Table 3 Aluminum smelting, cement production, and fossil fuel contributions to per capita emissions of greenhouse gases for selected countries with high per capita or rapidly growing primary aluminum production, 1987, ranked by greenhouse contribution per ton of primary aluminum smelted.

Country	1987 Alum Prod 10^3 ton	Percent Increase Al Prod. 1980-87	CO_2[eq] per t-Al	Pop. 10^6	Tons CO_2[eq]/person-yr Alum. Smelt	Cemt Prod.	Fossil Fuels
Australia	1024	238	39.6	16.7	2.43	0.18	14.0
Indonesia	201	201	34.6	180.5	0.04	0.03	0.6
Bahrain	180	43	31.4	0.5	8.10	0	32.3
Canada	1548	44	27.9	26.5	1.57	0.24	14.8
New Zealand	249	59	23.7	3.4	1.74	0.13	6.2
Brazil	844	224	22.5	150.4	0.13	0.08	1.2
Norway	798	21	21.5	4.2	4.08	0.20	7.48
Iceland	84	14	21.5	0.26	6.92	0.21	8.1
Global	16240	1.3	30.5	5292	0.094	0.097	3.81

Sources: Aluminum production, UNIDO(1989) and UN (1991); Population, fossil fuels and cement emissions, WRI (1990).

...ature Report

Greenhouse Worries for the Aluminum Industry

With its well-advertised recycling efforts, the *aluminum industry* has long cultivated a "green" image. But there are growing concerns in the business that it may soon be viewed as a "green*house*" industry instead. The CO_2 emissions from aluminum production are accompanied by small amounts of the relatively obscure gases tetrafluoromethane (CF_4) and hexafluoroethane (C_2F_6). These compounds are drawing increasing attention as very potent greenhouse gases that substantially boost the climatic impacts of the industry.

James W. Plumb, director of communications for the US-based Aluminum Association, told *EECC* that "anything the industry does that affects the environment in any adverse way is a big concern." But he also noted that the industry does not consider emissions of CF_4 and C_2F_6 to be "a terribly severe problem." Nevertheless, the industry is worried that its public image could be tarnished if the matter is not carefully handled. "Opinion research shows that we happen to enjoy a pretty high public regard.... We guard that very zealously," Plumb said.

The Aluminum Association therefore is being very tight-lipped about what it knows about the industry's emissions and what their climatic impacts might be. The motivation behind this reticence, Plumb says, is to avoid a disruptive and perhaps costly public debate based on incomplete, misleading information.

But Dean Abrahamson, an American professor who is trying to study the industry's emissions, bristles at the association's efforts to withhold information on the matter. "I am alarmed and distressed that the Aluminum Association is not being open about this very serious greenhouse issue," said Abrahamson. He believes that the association's silence is "evidence that they're trying to concoct a story instead of being open with it."

The dispute illustrates the kinds of problems that are likely to emerge as efforts to grapple with the climate problem go beyond CO_2 emissions and consider other compounds, and as the focus shifts to specific countries and industries. Disagreement on both emissions and impacts are likely, along with arguments over what the appropriate responses should be.

Background

Roughly 12-20 kilowatt-hours (kwh) of electricity are required to produce a kilogram of aluminum. By way of comparison, the average US household directly used over 24 kwh per day in 1987. On a global level, the industry may have used approximately 2.5%-3.0% of the world's electricity in 1989. Since roughly 27% of the world's CO_2 emissions from fossil fuels come from generating electricity, the aluminum industry worldwide might account for perhaps 0.7%-0.8% of global CO_2 emissions (using the simplifying assumption that all electricity is generated with the same fuel mix).

In addition to the CO_2 attributable to aluminum production, CF_4 and C_2F_6 are released directly during the smelting process. The chemicals have long been recognized as byproducts of aluminum smelting. But as they are nearly inert gases with no known toxic properties, and are produced in minute quantities, there seemed to be no reason to be concerned about them.

According to the Aluminum Association, the industry learned early in 1991 that the compounds were strong greenhouse gases. Abrahamson found out about the compounds later in the year, while working with a colleague at the University of Iceland to catalogue Iceland's sources of greenhouse gas emissions. Besides fish-related industries, the only sizable industry in the country is a single aluminum smelter. When Abrahamson investigated the atmospheric emissions of the smelter, he learned of CF_4 and C_2F_6 and since then has studied further the climatic implications of the gases.

Greenhouse Effects

The two gases are very persistent in the atmosphere, with lifetimes in excess of 10,000 years. For a given atmospheric concentration, they are also more effective at absorbing energy than some of the other more widely publicized halogenated compounds such as CFC-11 or 12.

The "global warming potentials" (GWPs) of the two gases, which are functions of both their atmospheric lifetimes and their molecular tendencies to absorb energy, are thousands of times greater than CO_2. GWPs were calculated for the Norwegian aluminum company Hydro Aluminum by Frode Stordal of the Norwegian Institute for

...en. According to Abrahamson, Stordal ...ed a GWP 8,400 times greater than that ...O_2 (using an integration period of 100 years).

GWPs are not perfect measures of the climatic implications of these gases, and their values can vary *considerably* depending on the assumptions used in calculating them. They are simplifications that some argue are misleading. Nevertheless, Stordal's figure — roughly comparable to Abrahamson's back of the-envelope GWP calculation of 10,900 — clearly indicates that the compounds are extraordinarily effective greenhouse gases. The GWPs are "certainly the largest of any compound I've ever looked at," Abrahamson told *EECC*.

But because much smaller quantities of CF_4 and C_2F_6 are produced each year than compounds such as CO_2, they collectively absorb far less energy in the atmosphere than CO_2 and several other prominent greenhouse gases. In 1988 about 5.9 billion metric tons of carbon were released globally as CO_2. CF_4 and C_2F_6 emissions, on the other hand, were on the order of 0.026 million metric tons and 0.0032 million metric tons, respectively.

Even so, CF_4 and C_2F_6 greatly amplify the climatic impacts of the aluminum industry. The relative importance of the two gases in aluminum production depends on the amounts of CO_2 emitted when the industry's electric power is generated. Where only hydropower is used, Abrahamson believes CF_4 and C_2F_6 may contribute nearly 85% of the total GWP contribution associated with producing aluminum. Where a conventional coal plant provides the electricity, CF_4 and C_2F_6 may contribute closer to 45% of the GWP. While many uncertainties remain, the conclusion that these gases are important within the industry is likely to be confirmed as additional work is done.

Estimates of CF_4/C_2F_6 Emissions

Abrahamson's work suggests that the aluminum industry is the only major emitter of the two compounds. If there are natural emissions, the amounts released are so small that researchers have been unable to detect them. Very small amounts of the compounds are produced artificially and deliberately outside of the aluminum industry, but these are of little consequence relative to those from the aluminum industry.

A recent reference book on aluminum production says "a total evolution of 1.5-2.5 kg CF_4 per metric ton of aluminum [is] produced. Sometimes C_2F_6 can be detected two or thr... magnitude less than CF_4."

Traces of the compounds are produced during normal operations, but most of the emissions of CF_4 and C_2F_6 result from a phenomenon called the "anode effect." In aluminum smelting, large quantities of electricity run between two electrodes, one of which is called an anode. This decomposes alumina in a process known as electrolysis. The result is molten aluminum. During the process, as the alumina is depleted within the smelting cell, conditions develop that impede the current flow between the electrodes. The anode voltage increases and electrical arcing occurs.

The frequency and duration of the anode effect — and hence emissions of CF_4 and C_2F_6 — vary from one smelter to the next. Industry sources say emissions can be as low as 0.2 to 0.3 kg of CF_4 per metric ton of aluminum produced, depending upon the technology used in smelting and how efficiently it is managed.

Uncertainty about the emissions of CF_4 and C_2F_6 is amplified further by the fact that no one routinely measures emissions of the compounds at most plants. Where measurements have been made, they are not widely and readily available.

An alternative to measuring industry emissions directly is to measure the annual increase in atmospheric concentrations of the gases, and to derive from those measurements estimates of total annual emissions. Since the gases remain in the atmosphere so long, the annual emissions should be close in magnitude to the annual increase of CF_4 and C_2F_6 in the atmosphere.

Abrahamson's calculations indicate that approximately 26,000 metric tons of CF_4 and 3,200 metric tons of C_2F_6 accumulated in the atmosphere during the 1980s. If all of those emissions originated from aluminum smelters, the average emission factors might be on the order of 1.6 kg of CF_4 and 0.2 kg of C_2F_6 per ton of primary aluminum produced.

Implications

The issue is significant not just for the aluminum industry, but also for regions of the world where aluminum production is concentrated. Of the estimated 17.8 million metric tons of aluminum produced by the world's primary aluminum industry in 1990, 23% was produced in the US, making it by far the world's largest producer. US production is concentrated in the Pacific Northwest and in the area served by the Ten-

...ey Authority, regions characterized by ...nt and inexpensive electricity when most ...e capacity was built.

Outside the US, other major producers are the former USSR (12.3%), Canada (8.8%), Australia (7%), Brazil (5.2%), China (4.8%), Norway (4.7%), and Germany (4.3%). Emissions will tend to increase and their regional distribution will change as the industry responds to the anticipated rapid growth in global aluminum demand during the next decade. Companies will probably build the new smelting capacity in areas where large amounts of cheap electricity are expected to be available, including parts of Latin America and the Middle East.

When CO_2 emissions from aluminum production are considered along with CF_4 and C_2F_6, the areas with the highest combined atmospheric impacts are those in which a large aluminum industry depends heavily on coal. Australia is one such example. According to Abrahamson's rough calculations, Australia's aluminum-related emissions, expressed in CO_2-equivalents (computed using his GWP estimate), amounted to 39.6 tons of CO_2-equivalent per metric ton of aluminum. Conversely, in countries such as Norway, where hydropower is the primary source of energy for the industry, the figure is 21.5 tons of CO_2-equivalent per metric ton of aluminum.

In some areas, factoring in CF_4 and C_2F_6 emissions dramatically alters greenhouse-gas emission profiles, particularly where aluminum is a major industry and where it is heavily dependent on hydropower. In New Zealand, for example, Abrahamson estimates that total annual per capita emissions from fossil fuels in 1987 were about 6.2 metric tons of CO_2-equivalent. At the same time, aluminum smelting emitted approximately 1.74 metric tons of CO_2-equivalent per capita, largely due to CF_4 and C_2F_6.

Industry's Position

According to Abrahamson, the industry is "very jumpy" about the issue. On 17 December 1991 the Aluminum Association met to discuss the gases' contribution to global warming. The meeting was for members of the industry only and was closed to outside observers. Abrahamson asked to attend and was refused. An association spokesperson told *EECC* that attendees included the European Aluminum Association, the French aluminum producer Aluminum Pechiney, Hydro Aluminum of Norway, and other US and European industry representatives.

The meeting's primary purpose was to encoura... an exchange of information on the issue among the industry's technical people, and to help develop a work plan to guide the industry's response. The work plan will be presented to a meeting of the association's Primary Aluminum Division this month.

In an interview with *EECC*, Plumb and M. Barry Meyer, the association's vice president for government relations, said that the industry is concerned about the situation, but is still trying to improve its assessment of the global magnitude and distribution of the emissions, the climatic impacts, and the options for reducing emissions should that prove to be necessary.

Reviewing the industry's position, Plumb said: "The bottom line really is that there's something there. It ought to be looked at. It may not be as serious as what Dr. Abrahamson has found.... But before we go out and criticize him and say his numbers are wrong, we'd better make damn sure that ours are arrived at in a good scientific way." While the industry has made some measurements of emissions, only a small number of facilities have been surveyed and different methodologies were used. Meyer and Plumb would not divulge their findings, saying that the numbers might mislead people. Plumb cautioned that "there's always the likelihood that the number's going to be misused. If it's the first number out, it seems to be the one that sticks."

Plumb and Meyer told *EECC* that to some extent emissions per unit of aluminum probably have declined as the smelting technology has improved over the years. The anode effect wastes expensive electricity. Therefore, technical improvements aim to minimize the unnecessary occurrence and duration of the anode effect. As technology has improved, they argued, the anode effect has become less common. They anticipate further improvements as technology progresses, and Plumb said that researchers are working on technologies in which the anode effect may be entirely avoided.

Better operating practices can also help to limit the anode effect, and they said that promoting such practices would be an early option if action is necessary. Roy H. Carwile, the association's director of environmental affairs, noted: "Everything we do to reduce these emissions also improves our energy picture."

But Plumb and Meyer admitted that since they do not know exactly what current emissions are, or what they have been in the past, they cannot accurately and precisely quantify the impacts of previous efficiency improvements on emissions. Nor can they estimate the potential of future efficiency improvements to reduce CF_4 and C_2F_6 emissions, since the relationship between those emissions and the anode effect is not precisely understood.

SOURCES

Dean Abrahamson has briefly summarized the greenhouse emissions from primary aluminum production in a short article to be published in *Ambio*, (vol. 21, no. 2, March 1992), and has prepared a full technical article for publication in early 1992. Professor Abrahamson can be reached at the Hubert Humphrey Institute of Public Affairs, University of Minnesota, 240 Humphrey Center, 301 19th Ave. South, Minneapolis, MN 55455, USA. Tel: +1 612 625 2338, Fax: +1 612 625 6351.

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Warren Haupin, "Environmental Considerations," Chapter 12 in A.R. Burkin (ed.), *Production of Aluminium and Alumina*, Chichester, UK: John Wiley & Sons, for the Society of Chemical Industry, 1987.

Industry Watch

Discovery of "New" Greenhouse Gases May Affect Aluminum Industry

Question: What greenhouse gases persist in the atmosphere for more than 10,000 years, have global warming potentials over 8,000 times greater than that of CO_2, and are traceable to virtually one source? Answer: tetrafluoromethane (CF_4, sometimes referred to as CFC-14) and hexafluoroethane (C_2F_6, called CFC-116 by some), two byproducts of the aluminum production process. Scientists recognized the compounds as greenhouse gases over a decade ago, but they have received little attention until recently, when Dean Abrahamson, a professor at the University of Minnesota (Minneapolis, Minnesota, USA), began to assess their relative importance and climatic impact.

The January issue of *GECR*'s sister publication, ***Energy, Economics and Climate Change***, reports that while global emissions of the two compounds are small compared with most other greenhouse gases (26,000 metric tons of CF_4 and 3,200 tons of C_2F_6 in 1988), they "greatly amplify the climatic impacts of the aluminum industry."

Aluminum production is an energy-intensive process, and rough calculations indicate that the industry worldwide contributes about 0.7%-0.8% of global CO_2 emissions, from the production of electricity used for primary aluminum smelting. In addition, it now appears that CF_4 and C_2F_6, which are produced by all smelters, contribute a comparable greenhouse forcing.

The relative greenhouse contribution of CF_4 and C_2F_6 compared with CO_2 depends on a given aluminum plant's source of electricity: where hydropower is used, according to Abrahamson, CF_4 and C_2F_6 may account for nearly 85% of the total global-warming-potential contribution associated with aluminum production. Where coal provides the power, the compounds contribute closer to 45%.

Adding the impact of CF_4 and C_2F_6 to CO_2 emissions from aluminum smelting may have important regional implications for the industry. Abrahamson notes that in New Zealand, for instance, aluminum smelting in 1987 emitted about 1.74 tons of CO_2-equivalent per capita, most of which is from CF_4 and C_2F_6. This figure is almost 30% of New Zealand's total annual per capita emissions from fossil fuels that year (6.2 tons of CO_2-equivalent).

CF_4 and C_2F_6 are produced by an "anode effect" that occurs during the smelting process; aluminum manufacturers have an incentive to minimize this effect because it wastes electricity. Spokesmen for the aluminum industry say that technological improvements are expected to reduce or in some cases eliminate CF_4 and C_2F_6 emissions, but it's worth noting that such improvements may be slow in coming to developing countries, where much of the new global smelting capacity is expected to be built over the next decade.

The aluminum industry has known about the gases' climatic implications for at least a year, and is in the midst of performing its own assessment of emissions levels. Spokesmen for the industry are currently reluctant to release any preliminary figures for fear that they might be misleading.

COMMENTARY ON

Henning Rodhe, Hillevi Eriksson, Kerstin Robertson, and Bo H. Svensson,
SOURCES AND SINKS OF GREENHOUSE GASES IN SWEDEN: A CASE STUDY,
AMBIO, **20**, 143-145 (May 1991)

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COMMENTARY ON

Henning Rodhe, Hillevi Eriksson, Kerstin Robertson, and Bo H. Svensson, SOURCES AND SINKS OF GREENHOUSE GASES IN SWEDEN: A CASE STUDY, *AMBIO*, **20**, 143-145 (May 1991).

Dean Abrahamson

Rodhe, *et al.*, have done a masterful job estimating the complex web of sources and sinks of greenhouse gases in Sweden. But, some general issues remain, among them:

<u>CF_4 and C_2F_6 emissions have not been considered</u>

Of the chlorofluorocarbons, Rodhe, *et al.* include CFC-11, CFC-12, and CFC-113 , but not emissions of CFC-14 (CF_4) and C-116 (C_2F_6). Primary aluminum smelting appears to be responsible for the increasing atmospheric inventory of both CF_4 and C_2F_6 ,[1] and Sweden has an aluminum smelter.

Combining the rate of increase of the atmospheric concentrations of CF_4 and C_2F_6 and global primary aluminum production data suggests average aluminum smelter emission factors of (1.6 ± 0.2)kgCF_4/tAl and (0.2 ± 0.02) kgC_2F_6/tAl.[2] Recent aluminum industry references indicate smelter CF_4 emissions of between 1.5 and 2.5 kilogram per ton aluminum and an order of magnitude or so less of C_2F_6.[3]

Preliminary measurements from primary aluminum smelters in Norway suggest a considerable variation in CF_4 emissions from one smelter to another,[4] perhaps related to the frequency and duration of the anode effect, a condition where the voltage across individual smelter electrolysis cells increases from the usual four volts to between 25 and 40 volts.[5]

CF_4 and C_2F_6 are extraordinarily stable, having atmospheric residence times in excess of 10,000 years.[6] They are greenhouse gases with band strength 4640 cm^{-2} atm^{-1} stp for CF_4 and 4861 cm^{-2} atm^{-1} for C_2F_6 .[7] They do not react in the atmosphere and so have no indirect greenhouse effect. They do not affect stratospheric ozone and so are not covered by the Montreal Protocol. They have no direct affect on human health nor do they cause any known non-greenhouse environmental impacts and so have not been subject to emission control measures.

The Intergovernmental Panel on Climate Change (IPCC) has not included CF_4 and C_2F_6 in its summaries of major greenhouse gases although the greenhouse contribution from these compounds, taken together, was about a third that of HCFC-22,[8] making them the fifth most important CFC in terms of direct greenhouse forcing during the decade of the 1980s. I estimate the global warming potential (GWP) of CF_4 and C_2F_6 , based on the band strengths, uncorrected for absorption bands of methane and nitrous oxide in the same spectral region, to be between 10,000 and 11,000 using a 100-year integration time. Stordal, using a more complete model, has estimated the 100-year GWPs to be 8,400.[9] The use, and definition, of GWP is now under review,[10] but CF_4 and C_2F_6 may be the most potent greenhouse gases being emitted in significant quantities. The very long atmospheric residence time of CF_4 and C_2F_6 result in their GWP increasing with increasing integration time, and, as these compounds cause essentially permanent global climate change, a GWP integration time longer than a few hundred years is appropriate for policy purposes.

Swedish smelters produced 81,500 tons of primary aluminum metal in 1987 resulting in emissions of about 208 tons of CF_4 and 26 tons of C_2F_6 if global average emission factors apply. These emissions are equivalent to about $2 \bullet 10^6$ tons of CO_2 using a 100-year GWP of 8,400.

Primary aluminum production also results in CO_2 emissions of about 1.6 tCO_2/tAl from carbon electrode consumption during the reduction of alumina (Al_2O_3),[11] plus the emissions resulting from primary energy used to produce the electricity and other energy inputs into production of bauxite, alumina, carbon electrodes, and aluminum. Aluminum smelters in the Nordic countries uses electricity produced from non-fossil sources and so the energy-related greenhouse gas emissions are small. In countries which produce electricity from coal or other fossil fuels, however, the energy-related greenhouse gas contributions are comparable to those from electrode consumption plus CF_4 and C_2F_6 .

Sweden's modest primary aluminum smelting industry results in comparatively small greenhouse gas emissions on a national per-capita basis, but not so for many other countries. Iceland and Norway, where aluminum smelting is a large part of the economy and geared for export rather than domestic consumption, have large per capita emissions from their primary aluminum industries, Table 1. Emissions from cement production, currently the only commodity other than fossil fuels individually represented in national greenhouse gas emission accounts, are also noted in Table 1.

I propose that national greenhouse gas budgets explicitly identify emissions from the production of other commodities, including aluminum, which results in significant releases of greenhouse gases.

<u>Bunker fuel emissions are not included</u>

Total carbon dioxide emissions from fossil fuels consumed in Sweden are estimated, in the companion paper by Eriksson,[12] to be 16 (15.5 to 17)Mton C yr^{-1}. Fuels consumed by Swedish ships or planes for international transportation appear not to have been included.

I have no data for Sweden, but in the case of Iceland, 1990 fossil fuel consumption produced CO_2 releases of 0.54 MtC *if* fuels consumed by Icelandic ships and aircraft in international travel are excluded, *but* 0.79 MtC if these fuels are included, an increase by 45 percent.[13] Further, 74 percent of the fuel consumed in international travel by Icelandic flag carriers was purchased in countries other than Iceland.

Norwegian data for 1990 show petroleum consumption, hence CO_2 emissions, by international shipping (exclusive of air carriers) to be equal to domestic consumption, each being 309 PJ.[14]

Data for the other Nordic countries may show a similar pattern when emissions resulting from their international air and sea carriers are included. It seems to me that all greenhouse gas emissions resulting from activities contributing to national economic indices, including fuel consumed in international transport regardless of the country in which the fuel is purchased, should be included in national greenhouse gas emission budgets.

<u>On credits for past actions</u>

Rodhe, *et al.* suggest that a credit be taken for avoided methane emissions because of wetlands drained in the past 100 or so years. This approach opens possibilities for mischief. Should, for example, a credit for avoided methane emissions be shared by Canada and the United States for killing most of the bison in the 1800s and to east African countries for killing their herds of wildlife more recently?

I suggest that none of these schemes to take credits for past human actions which have resulted in avoided contemporary releases are appropriate.

— • —

Table 1 Carbon dioxide from alumina reduction, CO_2 Al.Red., and estimated CF_4 plus C_2F_6 emissions from aluminum smelting, and carbon dioxide emissions from total national fossil fuel use (exclusive of bunker fuels) for the Nordic countries, 1987. CF_4 and C_2F_6 emissions are computed on the basis of estimated global average emission factors. All electricity used for aluminum smelting is produced from non-fossil fuel sources in the Nordic countries so there is no contribution to greenhouse warming from this aluminum smelting input. Equivalent carbon dioxide emissions, CO_2[eq], are computed using a 100-yr. GWP of 8,400 for both CF_4 and C_2F_6 .

Country	1987 Alum Prod 10^3 ton	Percent Increase Al Prod. 1980-87	CO_2 Al. Red. 10^3 ton	CF_4 + C_2F_6 ton	Pop. 10^6	Tons CO_2[eq] per person-yr Alum. Smelt.	Fossil Fuels
Denmark	-0-	-0-	-0-	-0-	5.1	-0-	11.94
Finland	-0-	-0-	-0-	-0-	5.0	-0-	10.57
Iceland	83.5	14	135	150	0.26	5.37	7.67
Norway	797.9	21	1280	1440	4.2	3.18	7.49
Sweden	81.5	-0-	130	147	8.3	0.16	7.07

Sources: Aluminum production, United Nations, *Industry and Development: Global Report 1989/90*, UN Industrial Development Organization, Vienna (1989). Population, cement, and fossil fuels for Denmark, Finland and Norway, World Resources Institute, *World Resources 1990-91*, Table 24.1, Oxford Univ. Press, New York (1990).Icelandic fossil fuel, Abrahamson, D., Jónsson, V.K., & Sólnes, J., "Iceland and Climatic Change," *Proceedings of First Nordic Inter-Disciplinary Research Conference on the Greenhouse Effect*, Copenhagen, 16-18 September 1991 (in press). Swedish fossil fuel, Eriksson, H., "Sources and Sinks of Carbon Dioxide in Sweden," *Ambio*, 20, 146-150 (May 1991).

REFERENCES

1. See, for example: Fabian, P., Borchers, R., Krüger, and Lal, S., "CF_4 and C_2F_6 in the Atmosphere," *Journal of Geophysical Research*, **92**, D8, 9831-9835 (1987).
2. Abrahamson, D., "Greenhouse Gas Emissions from Aluminum Smelting: An IPCC Oversight," submitted to *Nature*, December 1991.
3. Haupin, W.E., "Environmental Considerations," in Burkin, A.R. [ed], *Production of Aluminum and Alumina*, 176-187, John Wiley & Sons, Chichester (1987).
4. Hydro Aluminium, unpublished data, personal communication.
5. For theoretical considerations, see: Grjotheim, K., C.Krohn, M.Malinovský, K. Matiašovský, and J.Thonstad, *Aluminum Electrolysis: Fundamentals of the Hall and Héroult Process*, pages 275-6 and 281, Aluminum-Verlag, Düsseldorf, 2nd Edition (1982).
6. Fabian, *et al., op cit.*
7. Hansen, J., Lacis, A, and Prather, M., "Greenhouse Effect of Chlorofluorcarbons and Other Trace Gases," *Journal of Geophysical Research*, **94**, D13, 16417-16421 (1989).
8. Hansen, *et al., op cit.*
9. Stordal, F., Norwegian Institute for Air Research, personal communication.
10. IPCC, *1992 Update to the IPCC Scientific Assessment of Climate Change*, WMO and UNEP, Geneva, Draft (13 December 1991).
11. Øye, H.A., and Huglen, R., "Managing Aluminum Reduction Technology: Extracting the Most from Hall-Héroult," *Journal of Metals*, **42**, 23-28 (1990).
12. Eriksson, Hillevi, "Sources and Sinks of Carbon Dioxide in Sweden," *Ambio*, **20**, 146-150 (May 1991).
13. Abrahamson, D., Jónsson, V.K., & Sólnes, J., "Iceland and Climatic Change," *Proceedings of First Nordic Inter-Disciplinary Research Conference on the Greenhouse Effect*, Copenhagen, 16-18 September 1991 (in press).
14. "Ressursregnskap for energy 1990," SU nr. 36, Tabell 5, Statistik Sentralbyrå, Oslo (1991).

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SCIENTIFIC CORRESPONDENCE

GREENHOUSE GAS EMISSIONS FROM ALUMINUM PRODUCTION: AN IPCC OVERSIGHT

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SCIENTIFIC CORRESPONDENCE

GREENHOUSE GAS EMISSIONS FROM ALUMINUM PRODUCTION: AN IPCC OVERSIGHT

Dean Abrahamson*

The Intergovernmental Panel on Climate Change (IPCC) has overlooked two important greenhouse gases, CF_4 (CFC-14) and C_2F_6 (CFC-116). These gases have atmospheric residence times in excess of 10,000 years and have strong absorption bands in the atmospheric window. Of the chlorofluorocarbons, the radiative forcing of CF_4 and C_2F_6 during the 1980s was exceeded only by CFC-11, -12, -113, and HCFC-22.[1]

The only significant known anthropogenic source term for CF_4 and C_2F_6 is primary aluminum smelting. A small, yet unidentified, natural source of CF_4 is suspected. Fabian, *et al.*, estimate global emission rates of 28,000 tonne CF_4 and 3,200 tonne C_2F_6 per year based on the growth of atmospheric concentrations.[2] This suggests

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global average emission factors of about 1.6 $kgCF_4$ and 0.2 kgC_2F_6 per tonne of primary aluminum production. These rates are consistent with conventional aluminum industry estimates of 1.5 to 2.5 kg of CF_4 , and an order of magnitude or so less of C_2F_6 , produced and emitted to the atmosphere per tonne aluminum.[3]

Using the band strengths reported by Hansen, *et al.*, I estimate the Global Warming Potential (GWP) to be about 10,900 for CF_4 and C_2F_6 with 100-year integration time and without correction for the overlapping of absorption bands of CH_4 and N_2O. Stordal, using a more detailed model, has estimated the 100-yr GWP of CF_4 and C_2F_6 to be about 8,400.[4]

Average CF_4 and C_2F_6 emissions are thus equivalent to the greenhouse contribution of about 19.7 tonnes of CO_2 per tonne of aluminum using a 100-year GWP of 10,900. To the extent that CF_4 and C_2F_6 are produced during electrolysis cell anode effect, considerable variation is to be expected as the frequency of anode effect varies by about a factor of 20 from smelter to smelter.[5]

CF_4 and C_2F_6 may be the most potent greenhouse gases being emitted in large amounts. Not only do they have a very large greenhouse contribution per kilogram, they also cause an essentially permanent alteration in greenhouse forcing.

Aluminum smelting also results in large greenhouse gas emissions from production of electricity consumed during smelting, and CO_2 produced during alumina reduction to aluminum metal. Alumina reduction, $2\ Al_2O_3 + 3\ C \rightarrow 4\ Al + 3\ CO_2$, results, in practice, in emissions of between 1.5 and 2.2 tonnes of CO_2 per tonne of aluminum. Aluminum smelters consume between 13 to 20 MWh of electricity per tonne of aluminum depending on smelter efficiency. Greenhouse gas emissions from producing this electricity vary from at least 22 tonnes of CO_2 equivalent per tonne of aluminum when the electricity is produced by a conventional coal-fired power plant to essentially zero from hydropower.

Cement is the only primary commodity, other than fossil fuels, specifically included in IPCC and other standard tabulations of sources of greenhouse gas emissions. Yet, the total greenhouse contribution from primary aluminum production appears to be greater than that from cement production on a global basis and can be tens of times greater in countries with a large primary aluminum industry based on fossil-fuel generated electricity.

References

1. Hansen, J., Lacis, A. & Prather, M, *Journal of Geophysical Research* **94**, 16417-16421 (1989).
2. Fabian, P., Borchers, B.C., Krüger, B.C., & Lal, S., *Journal of Geophysical Research*, **92**, 9831-9835 (1987).
3. Haupin, Warren E., in A.R. Burkin [ed], *Production of Aluminum and Alumina*, Aluminium-Verlag, Düsseldorf (1987); and Grjotheim, K., *et al.*, *Aluminum Electrolysis: Fundamentals of the Hall and Héroult Process*, Aluminium-Verlag, Düsseldorf (1982).
4. Stordal, Frode, Norwegian Institute for Air Research, Oslo, personal communication.
5. Øye, H.A., and Huglen, R.: *Journal of Metals*, **42**, 23-28 (1990).

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August 1[illegible], 1991

VIA FAX: 44-344-856909

Sir John Houghton
Chairman
Working Group I
Intergovernmental Panel on Climate Change
Meteorological Office, Hadley Centre
London Road, Bracknell
Berkshire, RG 12 2SY
United Kingdom

Dear Sir John:

The purposes of this letter are (i) to call to your attention serious concerns expressed at the fourth plenary session of IPCC Working Group III regarding scenarios of future energy use and related greenhouse gas emissions and (ii) to urge your favorable consideration of an approach to these issues that should facilitate in a credible manner the important efforts of Working Group I.

You undoubtedly will review the report of the Working Group III meeting and receive observations concerning emissions scenarios issues from IPCC Chairman Bolin, from Working Group III Chairman Reinstein, from Energy and Industry Subgroup (EIS) Co-Chairman Yokobori, and from your representative, Dr. Bruce Callendar, all of whom were present during all or portions of the lengthy discussions of these issues. The comments herein are those of The Climate Council, which initially raised the emissions scenarios issue at the EIS meeting and which will continue its active participation in the IPCC.

I.

ROLE OF ENERGY EMISSIONS SCENARIOS IN CLIMATE PREDICTIONS

The choice by Working Group I of greenhouse gas emissions scenarios will greatly influence its climate change predictions based on current climate models. It is said that "the energy sector accounts for an estimated 46% (with an uncertainty range of 38-54%) of the enhanced radiative forcing resulting from human activities" during the period 1980-90. IPCC First Assessment Report, Working Group III Policymakers Summary, p. 1 (August 1990). Hence, the chosen scenario of future energy use and related emissions will play a central role in what Working Group I predicts about future climate change.

According to the "Schedule for the Preparation of a Supplement to the IPCC First Scientific Assessment Report" (revised version July 1991), an "update" of existing emissions scenarios, "which will enable a range of climate change predictions to be carried out," currently is in process and is scheduled to be completed by November 30, 1991. Our understanding is that, at its July 8-11, 1991 meeting in Shepperton, the Working Group I task force on emissions scenarios decided that the "energy sector component [of emissions scenarios] will be based on the 1990 EIS scenario to 2025," which "will be extended to 2100 using econometric models" and other assumptions, such as those provided by the World Bank concerning population. See Summary of Conclusions of Working Group I task force, attached as Appendix F to Draft Report of IPCC Working Group III, August 5-8, 1991.

(August)

II.

CONCERNS EXPRESSED ABOUT LONG-TERM ENERGY SCENARIOS

At the August 6-7, 1991 meeting of the EIS, there was lengthy discussion of the substantial risks associated with developing and using long-term scenarios of energy use and related emissions. A highly abridged summary of the discussion is set forth in the EIS Co-Chairman's report forming part of the report of the fourth plenary session of Working Group III.

The discussion grew out of the widespread realization that, in order not to jeopardize the credibility of the IPCC, great care must be taken in both the development and the presentation of energy and energy-related emissions scenarios. There were numerous expressions of concern by national delegations, as well as by representatives of the International Energy Agency and of the International Atomic Energy Agency, about using energy scenarios covering periods of more than 10 to 20 years. It was clear that the concerns increase greatly as the time period of the scenario is extended. As one delegate from an OECD nation succinctly stated, "it is impossible to make reliable energy forecasts of more than 10 to 15 years, and anything beyond that is pie in the sky."

Several speakers pointed out that even short-term energy forecasts often have been way off the mark. Examples were given of errors by factors of three or more.

No disagreement was expressed with the idea stated by several delegations that energy forecasts for as much as 50 to 100 years, to coincide with the Working Group I climate predictions to the year 2100, were inherently unreliable.

Numerous, imponderable factors will determine whether there may be any relationship at all between an energy scenario and future reality. A prime factor is whether new technology will be invented, will receive sufficient capital for deployment, and will be accepted by the public. As Jessica Mathews, Vice President of the World Resources Institute, observed in her newspaper column this past week, "Technology forecasts reliably produce comic results." The Washington Post, p. A21 (August 15, 1991).

Other important factors that cause skepticism about longer-range energy scenarios include population growth, economic growth and changes in the sectoral makeup of each nation's economy, changes in consumer preferences and choices about lifestyle, and market price responses to these factors and to government policies.

The ability to foresee these changes decreases over time and rapidly moves from what, at best, are informed guesses in the very near term to fanciful speculation in the longer term.

To make matters even more complicated, questions arose as to how it is possible to develop credible scenarios of future global greenhouse gas emissions when so much more work must be done to have confidence in current emissions inventories. It was noted that, subject to availability of funding, the draft IPCC guidelines for a methodology to determine national emissions inventories is scheduled for mid-1992, with final guideline methodology not scheduled until June 30, 1993.

In these circumstances, some delegations at the EIS meeting urged that Working Group III advise Working Group I that it should not use energy and energy-related emissions scenarios of more than 20 years' duration. It was recognized, however, that Working Group I appears to be determined to publish updated climate change predictions to the year 2100. In a good-faith effort to avoid prolonged and contentious debate within Working Group III and between Working Groups I and III, it also was recognized that it might be desirable, if possible, to devise an approach to accommodate Working Group I's determination, the concerns stated above, and IPCC credibility.

An important theme emerged as a possible way to assure that policymakers, the media, and the public would not be misled as a consequences of Working Group I's using long-term energy and energy-related emissions scenarios. This was that there should be full and adequate disclosure by Working Group I of the facts that:

(i) the Working Group I predictions of climate change are based to material degree on only a hypothetical scenario of energy and energy-related emissions, which scenario is neither a prediction, nor a projection, nor a forecast; and

(ii) for the various reasons described above, no assumption should be made that the scenario will be realized in actuality.

As stated in the report of the EIS Co-Chairman to Working Group III, the "Subgroup recommended its co-chairs to forward, through the Working Group 3 Chair, a clearly worded caution to the Chairs of WG I and of the IPCC, pointing out the reservations expressed, the uncertainty inherent in such scenarios, and asking that IPCC reports carefully note that such scenarios should not be used as predictions."

This approach is entirely in keeping with the wise comments of IPCC Chairman Bolin, as stated in the draft report of the Working Group III plenary session: "In updating them [emissions scenarios], all assumptions should be clearly spelled out and all resulting changes explained clearly. Careful attention should be paid to the difference between the inherent uncertainties due to inadequate knowledge of the behaviour of the climate system on the one hand and the sensitivity of emissions scenarios to alternative assumptions about future emissions on the other."

III.

ISSUES TO BE RESOLVED

In our view, full and adequate disclosure by Working Group I requires dealing appropriately with the following matters:

1) Explanation of the dependency of the climate change predictions on the energy and energy-related emissions scenario.

2) Meaningful distinction between scenarios, on the one hand, and predictions, projections, and forecasts, on the other.

3) Description of the numerous reasons why, in light of experience, one should not assume energy and energy-related emissions scenarios, especially those covering more than 10 or 20 years, will be realized in actuality.

4) Explanation of the methodology and assumptions of the IPCC 1991 Reference Scenario, the differences between that scenario and Scenario "A" used in the First Assessment Report, and the reasons for, and consequences of, changing the scenarios. (As you know, the [illegible] Reference Scenario depicts carbon dioxide emissions from the energy sector in the year 2025 at a level that is more than 25 percent higher than the level in Scenario "A.")

5) Location and format of the foregoing material in the Working Group I "update" report, including any policy-makers or executive summary.

We have great concern about both the substance and manner of presentation of information on emissions scenarios in Working Group I's First Assessment Report. For example, the all-important Policymakers Summary introduces the reader to the complex issues covered by Working Group I with bold-face assertions such as "We are certain of the following. . .," "We calculate with confidence that. . .," "Based on current model results, we predict. . .," and "Our judgment is that. . .;" but, it is not until page 19 (of 26) that there is any mention of the "uncertainties in the above climate predictions [that] arise from our imperfect knowledge of future rates of human-made emissions . . . ." The two-sentence elaboration, referring without explanation to "various complex economic and sociological factors," is not adequate in our view.

It is our hope that similar problems can be avoided in the forthcoming "update."

IV.

PROPOSAL

In order to assure that the Working Group I "update" reasonably reflects your new scientific assessments in light of the need for full and adequate disclosure of the matters described above, and to resolve potential differences of opinion in an amicable, professional, and efficient manner, we request the opportunity, along with such other energy experts from governments and NGOs as might be interested, to develop with you and/or the authors of the "update" an agreed presentation of necessary information, as outlined in Part III of this letter.

Geneva

Sir John Houghton
August 19, 1991

We note that a drafting session of "greenhouse gases lead authors" is scheduled for October 16-18 in Les Diablerets, Switzerland. It occurred to us that such session might be a convenient time to attempt to resolve these issues. The objective would be to develop, if possible, an agreed approach prior to the sixth plenary session of the IPCC on October 29-31, but, in any event, prior to the January 13-15 session of Working Group I. Refinement of final language might have to await ultimate decisions by Working Group I on how it wanted to present the substance of its "update."

We recognize fully that you will have a better idea than we do about what would make the most sense from the perspective of Working Group I's work schedule. Hence, we are prepared to be quite flexible, subject only to two principal qualifications: (i) our commitments to participate in sessions of the INC, of IPCC Working Group III, and of the EIS; and (ii) our desire to reach final, constructive agreements on these matters so they may be reflected in the Working Group I "update" report, thereby avoiding a contentious issue when that report is submitted for approval by the IPCC at its seventh plenary session, which we understand is scheduled for February 13-15, 1992.

If you, or Dr. Callander, if you prefer, would like to discuss these matters, please call me at (202) 457-6512, my direct line, or you can fax me at (202) 457-6315. 202-457-6512

We appreciate your consideration.

Sincerely yours,

Donald K. Pearlman

Donald K. Pearlman

cc: IPCC Chairman, Bert Bolin
IPCC Working Group III Chairman,
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Fax Memo

TO: Katie McGinty FAX: 202-224-0580
ORGANIZATION: Senator Gore's office

FROM: Brad Hurley FAX: 617-648-8707 ☎ 617-648-8700
DATE: Sept. 18, 1991 PAGES (Including this): 7
RE: Pearlman's letter.

Katie,

This is a fax of a fax (of a fax of a fax, etc.) — hope it's legible. Pearlman is currently in Nairobi at the INC talks.

If it's not too inconvenient, would it be possible for you to fax me the Tellus article on sulfate aerosols? We don't get Tellus here, and I'd love to see the paper.

Cheers,

Brad