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ANALYSIS OF GLOBAL WARMING MITIGATION BY WHITE REFLECTING SURFACES

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BACKGROUND

IPCC Fourth Assessment Report say that Earth's average temperature increase is due to anthropogenic causes.

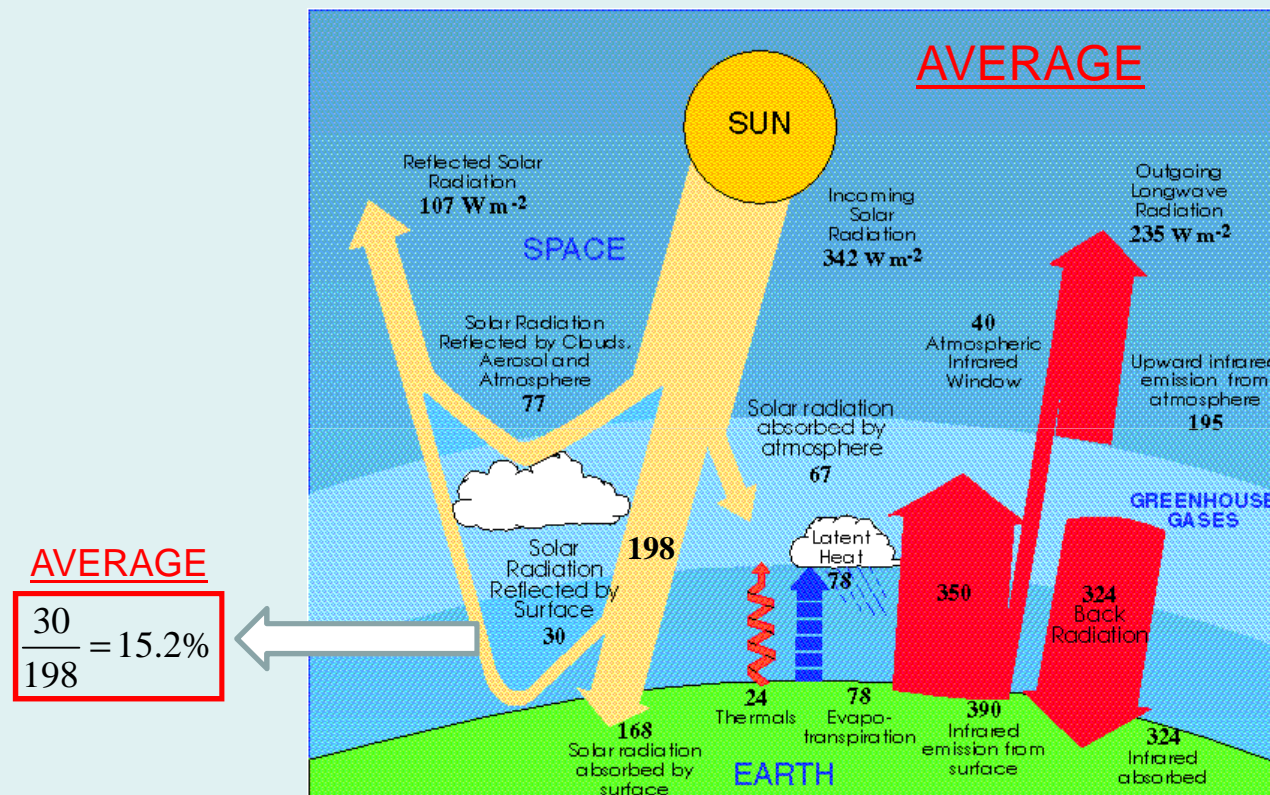
Approaches to tackle Global Warming are aimed to prevent CO₂ release into atmosphere

These methods are also supported by recent policies as:

- Emission Trading Scheme (ETS)
- Kyoto Protocol
- European 20-20-20 Programme

**Are there complementary approaches to tackle
Global Warming?**

The answer may be found in the Earth thermal balance.



An important role is played by Earth Albedo = shortwave energy reflected by the Earth towards outer space.

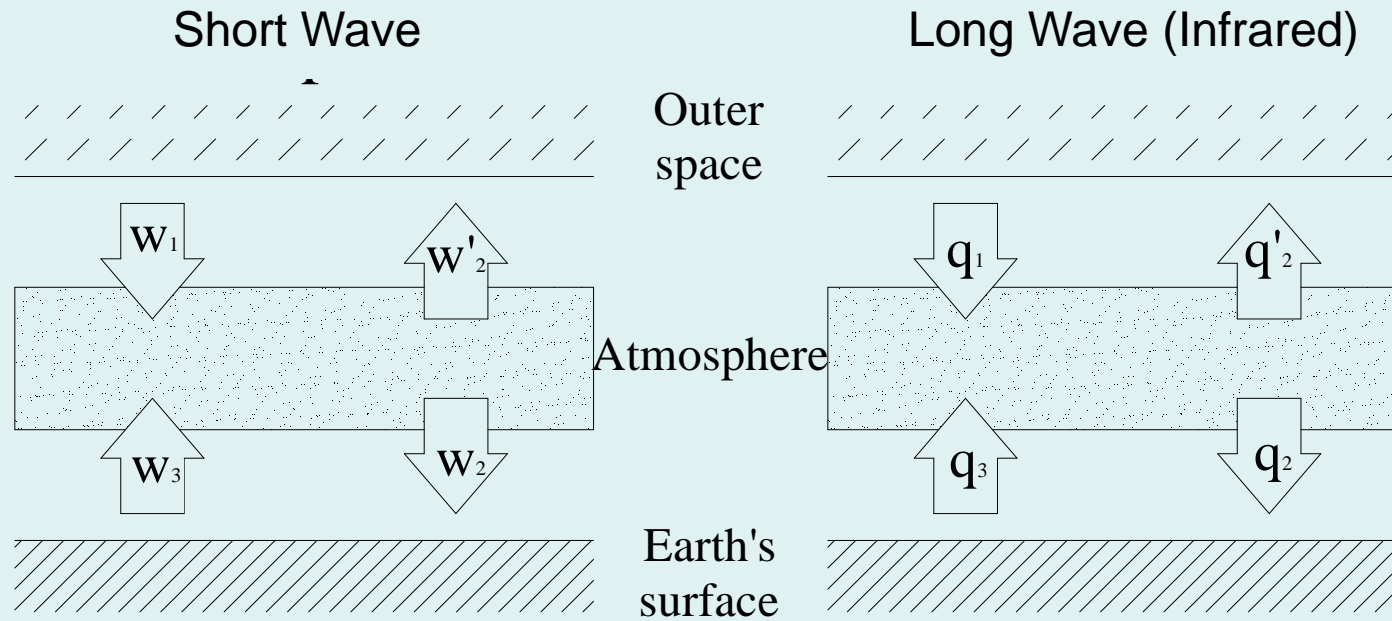
- An increase on Earth albedo corresponds on Earth temperature decrease.
- The proposal is to artificially slightly modify Earth albedo in order to compensate Earth temperature increase due to Global Warming



To make it viable and
controllable

1. A proper thermal balance model has been formulated which links Earth albedo to Earth temperature
2. A proper relation has been also proposed which links Earth albedo to CO₂ concentration variation

MODEL SCHEME



Energy balance (both in short and long wave spectrum) is governed by:

$$w_3 + w_1 + q_3 + q_1 - w_2 - w'_2 - q_2 - q'_2 = C_{atm} \cdot \frac{dT_{atm}(\tau)}{d\tau} \quad \text{(Atmosphere)}$$

$$w_2 + q_2 - w_3 - q_3 = C_{Earth} \cdot \frac{dT_{Earth}(\tau)}{d\tau} \quad \text{(Earth)}$$

MODEL MOTHER RELATIONS

$$w_3 + w_1 + q_3 + q_1 - w_2 - w_2' - q_2 - q_2' = C_{atm} \cdot \frac{dT_{atm}(\tau)}{d\tau} \quad (\text{Atmosphere})$$

$$w_2 + q_2 - w_3 - q_3 = C_{Earth} \cdot \frac{dT_{Earth}(\tau)}{d\tau} \quad (\text{Earth})$$

Earth surface (C_{Earth}) and atmosphere (C_{atm}) “heat capacities” represent equivalent heat capacities because only a portion of each body takes part to energy balance. Determination of C_{Earth} and C_{atm} has been carried out by calibrating the model with the climatic data reported by the Fourth Assessment Report by IPCC.

MODEL OUTPUT

By considering a steady state condition:

T_{Earth} (Earth temperature) may be attained by the following relation:

$$T_{\text{Earth}} = \frac{-1}{\sigma_0 \alpha_3 (-1 - \rho_2 + \rho_2 r_3 r_2 - r_3 r_2 - \tau_2 r_3 r_2 + \tau_2)} [-\sigma_0 \alpha_3 \cdot (\rho_2 - \tau_2 - 1) \cdot [-\sigma_0 \alpha_3 \cdot (\rho_2 - \tau_2 - 1) \cdot \omega_1 \cdot (r_3 r_2 - 1) \cdot (t_2 \rho_2 \rho_3 - t_2 r_3 \rho_2 \rho_3 + \tau_2 \rho_3 t_2 r_3 - t_2^2 r_3 \rho_3 - \rho_3 r_2 - \rho_3 r_3 r_2 + r_2^2 \rho_3 r_3 + \rho_3 - \tau_2 \rho_3 t_2 + r_3 r_2 + t_2 - 1 + r_2 + - r_2^2 r_3 + t_2^2 r_3 + t_2 r_3)]^{\frac{1}{2}} \cdot (r_3 r_2 - 1)]^{\frac{1}{2}}$$

α_3 infrared Earth's surface absorption coefficient
 ρ_2 infrared atmosphere reflection coefficient
 ρ_3 infrared Earth's surface reflection coefficient
 σ_0 Stefan-Boltzmann constant

τ_2 infrared atmosphere transmission coefficient
 ω_1 incoming solar flux (342 W/m²)
 r_2 atmosphere reflection coefficient in the solar spectrum
 r_3 Earth's surface albedo in the solar spectrum
 t_2 atmosphere transmission coefficient in the solar spectrum

As you can see, T_{Earth} depends on r_3 (Earth Albedo) which is artificially and impactless modifiable.

$$\left(\frac{dT_{\text{Earth}}}{dr_3} \right) = \text{Sensibility of } T_{\text{Earth}} \text{ to albedo}$$

Earth temperature average increase since preindustrial era to the present day is 0.67 °C (IPCC Fourth Assessment Report).

Albedo modification can produce a 0.67 °C reduction
in Earth average temperature



The proposed model shows that the average absorption coefficient of Earth surface a_3 ($= 1-r_3$) in shortwave spectrum is to be reduced from:

0.848 to 0.834 (a_3).

If albedo modification is achieved by artificial “laying high albedo surfaces (albedo $r = 0.9$)”, the required area S_r is given:

$$S_r = \frac{(a'_3 - a_3) \cdot S_T}{1 - r - a_3}$$

a_3 Earth's surface absorption coefficient in the visible spectrum

a'_3 Earth's surface absorption coefficient in the visible spectrum modified by laying white reflecting surfaces

r artificial surface albedo

S_T extent of Earth's surface

S_r is $9.36 \cdot 10^6 \text{ km}^2$ @ $r = 0.9$

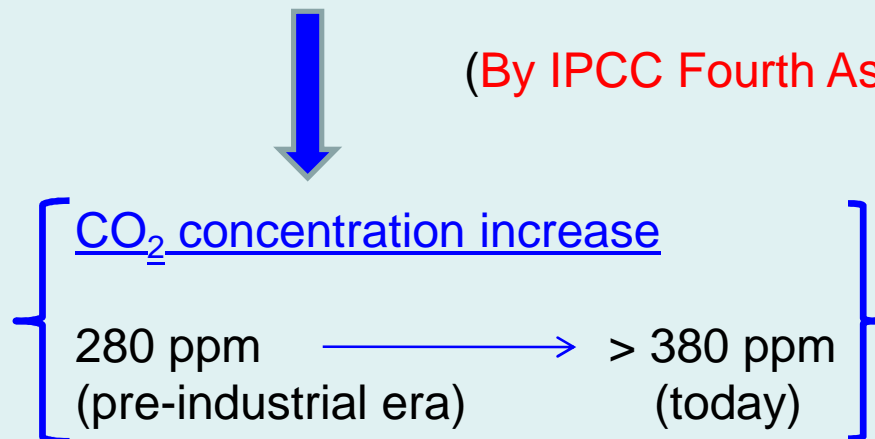
(This is roughly the area of USA)

To relate temperature increase to CO₂ concentration variation, the following hypothesis has been considered:

CO₂ concentration increase since preindustrial to the present day is the only cause which yielded the Earth temperature increase.

$$\begin{array}{ccc} +1.23 \cdot 10^{12} \text{ tCO}_{2\text{eq}} & \longrightarrow & + 0.67 \text{ }^\circ\text{C} \pm 0.18 \text{ }^\circ\text{C} \\ \text{(CO}_{2\text{eq}} \text{ total mass increase)} & & \text{(Earth temperature increase)} \end{array}$$

(By IPCC Fourth Assessment Report data)



The High Albedo Surface area S_{eq} required to offset the effect of introducing in the atmosphere 1 ton of CO_{2eq} has been obtained as follows:

$$S_{eq} = \frac{S_r}{\Delta CO_{2eq}} = \frac{9.36 \cdot 10^{12} \text{ m}^2}{1.23 \cdot 10^{12} \text{ tCO}_{2eq}} = 7.6 \frac{\text{m}^2}{\text{tCO}_{2eq}}$$

S_r = High Albedo Surface area required to offset a 0.67 °C Earth temperature increase.

ΔCO_{2eq} = CO_{2eq} total mass increase from preindustrial to the present day

In terms of Radiative Forcing, a drop of 0.28 W/m² is obtained for each 10⁶ km² of surfaces with 0.9 albedo.

HOW TO ARTIFICIALLY MODIFY ALBEDO?

SOLUTIONS AND APPLICATIONS

1. Whitening treatment of industrial building roofs
2. Whitening treatment of highways and parking areas
3. Reactivation of unused salt lakes
4. Installation of new saltworks in low value areas (industrial areas or petrochemical sites on the coasts)
5. Plantings of species with particular chromatic properties
6. Artificial white reflecting floating islands

(Italian patents PG2006A0086 and PG2007A0009)

ALREADY CERTIFIED EXAMPLES



A typical reflecting painting realized on silos (Perugia, Italy)



Reflecting covering of a Total Service station (Fiorenzuola, motorway A1, Italy)

AVOIDED CO₂ EMISSIONS (COMPARISON WITH RENEWABLE SOURCES)

<i>Technology</i> (CO _{2eq} Emissions)	<i>Reference Technology</i> (CO _{2eq} Emissions)	<i>Avoided emissions</i>
		gCO _{2eq} /kWh
Ribbon silicon (35 gCO _{2eq} /kWh _e)	Combined cycle gas turbine (400 gCO _{2eq} /kWh _e)	365
Photovoltaic mono/multicrystalline silicon (45 gCO _{2eq} /kWh _e)		355
Wind generator (6 gCO _{2eq} /kWh _e)		394
Hydroelectrical (15 gCO _{2eq} /kWh _e)		385
Thermal solar (flat collector) (20 gCO _{2eq} /kWh _t)	Boiler stoked with natural gas (230 gCO _{2eq} /kWh _t)	210

<i>Technology</i>	<i>Avoided emissions</i>
	kgCO _{2eq} /m ²
White Reflecting Surfaces (0.9 albedo)	130

TECHNICAL ECONOMICAL EFFECTIVENESS

The mentioned tables do not immediately allow comparison of renewable energy sources with white reflecting technology in terms of avoided CO₂, as the former are systems to produce energy whereas the latter is a system to mitigate Earth average global temperature.

A comparison method is proposed, based on the cost required to avoid the same amount of released CO_{2eq}.

$$C_{CO_2} = \frac{CP_{FR} - CP_{FF}}{E_{FF} - E_{FR}} \left[\frac{c\text{€}}{\text{kgCO}_{2eq}} \right]$$

CP_{FR}	Energy unit production cost for renewable sources [c€/kWh]
CP_{FF}	Energy unit production cost for traditional sources [c€/kWh]
E_{FR}	CO _{2eq} emissions with renewable energy sources [kgCO _{2eq} /kWh]
E_{FF}	CO _{2eq} emissions with traditional energy sources [kgCO _{2eq} /kWh]

TECHNICAL ECONOMICAL EFFECTIVENESS

Technology	Avoided CO_{2eq} costs
	c€/KgCO_{2eq}
Ribbon silicon	59.0
Photovoltaic mono/multicrystalline silicon	60.5
Thermal solar (flat collector)	30.0
Wind generator	3.8
Hydroelectrical	2.6
Reflecting surface made by lime paint	4.0
Reflecting surface made by vinyl acrylic paint	5.0

CONCLUSIONS

Albedo Control can be an important complementary method to compensate greenhouse gases effect on Earth temperature because of:

- Lower costs (4-5 c€/KgCO_{2eq}) than renewable energy sources for avoiding the same CO₂ effect;
- Easiness and short time for installation;
- Opportunity for countries where higher levels of insulation make the system even more effective and valuable in terms of avoided CO₂

ABCD RESEARCH PROJECT

(Albedo – Building green – Control of global warming – Desertification)

A cooperation research project is going to start among Italian research centers and Tunisian scientific and operative agencies. The project main purpose are:

- verify and certify the performances of the proposed technology;
- include Albedo Control method into ETS system

FOR MORE INFO

albedocontrol.com