

## CONSENSUS SCIENCE – A SUMMARY OVERVIEW

By Alan Siddons, last updated April 2011

From a UK government site:

<http://www.bis.gov.uk/go-science/climatescience/greenhouse-effect>

After gas molecules absorb radiation, they re-emit it in all directions. Some of the infrared radiation absorbed by gases in the atmosphere is therefore re-radiated out towards space and eventually leaves the atmosphere, but some is re-radiated back towards the Earth, warming the surface and lower atmosphere (illustrated by the 'back radiation' term in Figure 2). This warming is known as the greenhouse effect and the gases that are responsible for it are known as greenhouse gases.

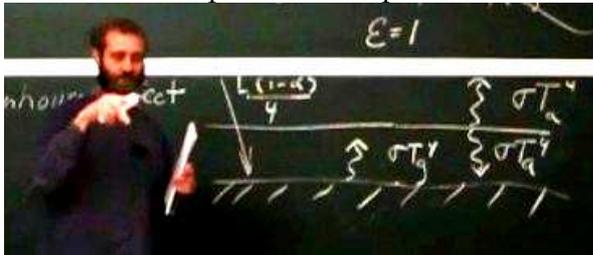
**Gavin Schmidt**

The factor of two for the radiation emitted from the atmosphere comes in because the atmosphere radiates both up and down.

<http://www.realclimate.org/index.php/archives/2007/04/learning-from-a-simple-model/>

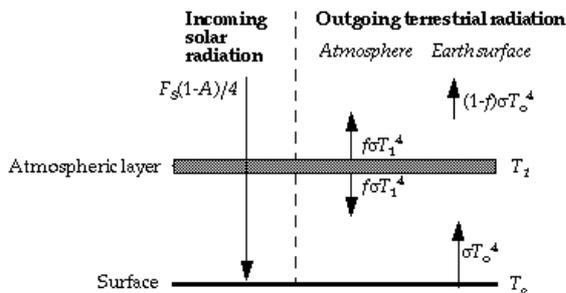
**Professor Archer**

Download the Chapter 3 *The Greenhouse Effect* video and you will see professor Archer sketch out the same explanation as professor Lindzen's.



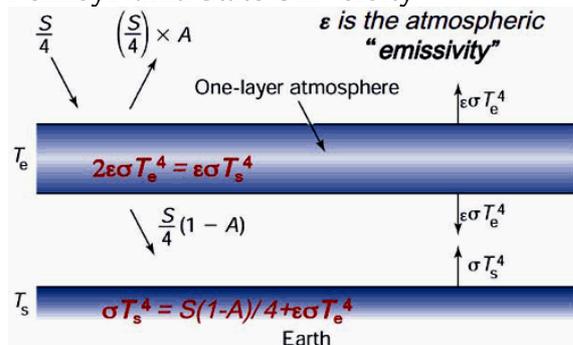
<http://geoflop.uchicago.edu/forecast/docs/lectures.html>

Harvard University's version:



<http://acmg.seas.harvard.edu/people/faculty/djj/book/bookchap7.html>

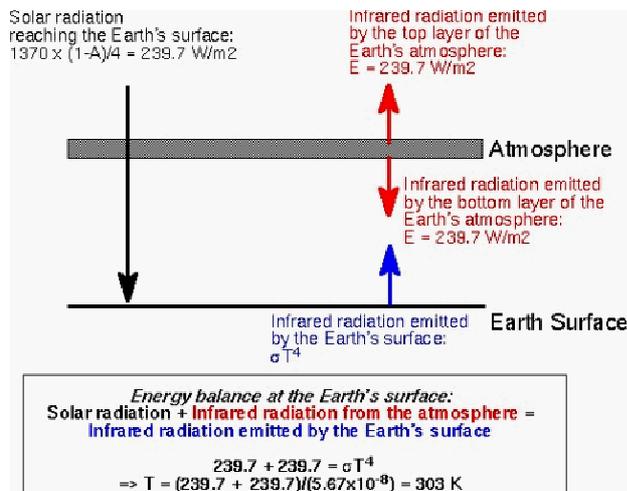
Pennsylvania State University



<https://www.e-education.psu.edu/meteo469/node/198>

## University of Washington's Department of Atmospheric Sciences.

The instructor omits the algebraic camouflage and uses simple arithmetic instead. In other words, he does exactly what the others do except he makes it CLEAR.

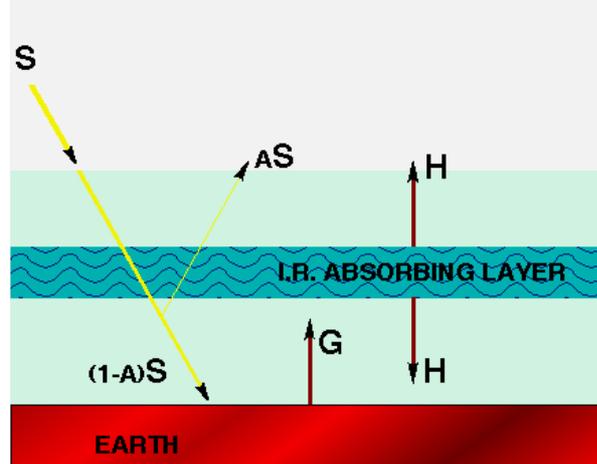


[http://www.atmos.washington.edu/2002Q4/211/notes\\_greenhouse.html](http://www.atmos.washington.edu/2002Q4/211/notes_greenhouse.html)

## Columbia University

ALL of these depictions are based on what had been earlier believed about glass enclosures. These things don't happen in a glass enclosure, though, so the experts forced themselves to insist that they DO happen between the atmosphere and the earth's surface.

A SIMPLE MODEL OF THE GREENHOUSE EFFECT



[http://eesc.columbia.edu/courses/ees/climate/lectures/gh\\_kushnir.html](http://eesc.columbia.edu/courses/ees/climate/lectures/gh_kushnir.html)

## Colorado University

Don't forget the *coup de grâce*! Check out the University of Colorado's demo:

<http://phet.colorado.edu/en/simulation/greenhouse>

Run the demo and see that this "effect" is EXACTLY the same in a glass greenhouse, they claim. The University of Colorado is a prime SOURCE of the IPCC's material.

An indication of just how “settled” the “science” is can be gleaned from these quotes:

....the popular depiction of the [greenhouse] effect as resulting from an infrared ‘blanket’ can be seriously misleading, and, as a result, much of the opposition that focuses purely on the radiation is similarly incorrect. — **Richard Lindzen**

<http://www.ilovemycarbon dioxide.com/Lindzen/LMD-March31-2011.pdf>

When you pile all of the layers of greenhouse gases in the atmosphere on top of one another, they form a sort of radiative blanket, heating the lower layers and cooling the upper layers. —

**Roy Spencer**

<http://www.drroyspencer.com/2009/12/what-if-there-was-no-greenhouse-effect/>

The list below that was compiled in December 2008, some links no longer work:

#### **NASA**

Why is this process called "The Greenhouse Effect?"

Because the same process keeps glass-covered greenhouses warm. The Sun heats the ground and greenery inside the greenhouse, but the glass absorbs the re-radiated infra-red and returns some of it to the inside.

<http://www-istp.gsfc.nasa.gov/stargaze/Lsun1lit.htm>

#### **NASA**

A real greenhouse is made of glass, which lets visible sunlight through from the outside. This light gets absorbed by all the materials inside, and the warmed surfaces radiate infrared light, sometimes called "heat rays", back. But the glass, although transparent to visible light, acts as a partial barrier to the infrared light. So some of this infrared radiation, or heat, gets trapped inside.

<http://www-airs.jpl.nasa.gov/News/Features/FeaturesClimateChange/GreenhouseEffect/>

#### **NASA**

The "greenhouse effect" is the warming of climate that results when the atmosphere traps heat radiating from Earth toward space. Certain gases in the atmosphere resemble glass in a greenhouse, allowing sunlight to pass into the "greenhouse," but blocking Earth's heat from escaping into space.

[http://www.gsfc.nasa.gov/gsfc/service/gallery/fact\\_sheets/earthsci/green.htm](http://www.gsfc.nasa.gov/gsfc/service/gallery/fact_sheets/earthsci/green.htm)

#### **Dept of Atmospheric and Oceanic Science at the University of Maryland**

A real greenhouse is enclosed by glass walls and ceilings. Glass is highly transparent in the visible wavelengths of the sun, so sunlight freely passes into the greenhouse. However, glass is highly absorbing in the infrared wavelengths characteristic of emission by earth's surface. Therefore, the infrared radiation emitted by the surface is efficiently absorbed by the glass walls and ceiling, and these surfaces, in turn, radiate energy back into the interior of the greenhouse, as well as outward to the environment. But clearly, a large portion of the infrared radiation from the surface does not pass outward from the greenhouse, and the equivalent energy is contained within the greenhouse environment.

<http://www.atmos.umd.edu/~owen/CHPI/IMAGES/grnhs1.html>

#### **Bigelow Laboratory for Ocean Sciences**

In a greenhouse, visible light (e.g., from the Sun) easily penetrates glass or plastic walls, but heat (in the form of infrared radiation) does not. The greenhouse effect refers to the physical process by which atmospheric gases allow sunlight to pass through but absorb infrared radiation thus acting like a blanket trapping heat.

[http://www.bigelow.org/virtual/handson/greenhouse\\_make.html](http://www.bigelow.org/virtual/handson/greenhouse_make.html)

### **The U.S. government's Environmental Protection Agency**

The energy that is absorbed is converted in part to heat energy that is re-radiated back into the atmosphere. Heat energy waves are not visible, and are generally in the infrared (long-wavelength) portion of the spectrum compared to visible light. Physical laws show that atmospheric constituents—notably water vapor and carbon dioxide gas—that are transparent to visible light are not transparent to heat waves. Hence, re-radiated energy in the infrared portion of the spectrum is trapped within the atmosphere, keeping the surface temperature warm. This phenomenon is called the "greenhouse effect" because it is exactly the same principle that heats a greenhouse.

<http://www.epa.gov/ne/students/pdfs/activ13.pdf>

### **Fort Lewis College, Colorado**

This partial trapping of solar radiation is known as the greenhouse effect. The name comes from the fact that a very similar process operates in a greenhouse. Sunlight passes relatively unhindered through glass panes, but much of the infrared radiation reemitted by the plants is blocked by the glass and cannot get out. Consequently, the interior of the greenhouse heats up, and flowers, fruits, and vegetables can grow even on cold wintry days.

<http://physics.fortlewis.edu/Astronomy/astronomy%20today/CHAISSON/AT307/HTML/AT30702.HTM>

### **Planet Connecticut.org**

Glass is transparent to sunlight, but is effectively opaque to infrared radiation. Therefore, the glass warms up when it absorbs some of the infrared radiation that is radiated by the ground, water, and biomass. The glass will then re-radiate this heat as infrared radiation, some to the outside and some back into the greenhouse. The energy radiated back into the greenhouse causes the inside of the greenhouse to heat up.

<http://www.planetconnecticut.org/teachersadministrators/pdfs/lesson1.pdf>

### **United Nations Framework Convention on Climate Change**

Greenhouse gases make up only about 1 per cent of the atmosphere, but they act like a blanket around the earth, or like the glass roof of a greenhouse -- they trap heat and keep the planet some 30 degrees C warmer than it would be otherwise.

[http://unfccc.int/essential\\_background/feeling\\_the\\_heat/items/2903.php](http://unfccc.int/essential_background/feeling_the_heat/items/2903.php)

### **How Stuff Works**

Light passes through the glass into the greenhouse and heats things up inside the greenhouse. The glass is then opaque to the infrared energy these heated things are emitting, so the heat is trapped inside the greenhouse.

<http://home.howstuffworks.com/question238.htm>

### **Enviropedia.org.uk**

Greenhouse gases like water vapour, carbon dioxide, methane and nitrous oxide trap the infrared radiation released by the Earth's surface. The atmosphere acts like the glass in a greenhouse, allowing much of the shortwave solar radiation to travel through unimpeded, but trapping a lot of the longwave heat energy trying to escape back to space. This process makes the temperature rise in the atmosphere just as it does in the greenhouse. This is the Earth's natural greenhouse effect and keeps the Earth 33°C warmer than it would be without an atmosphere, at an average 15°C. In contrast, the moon, which has no atmosphere, has an average surface temperature of -18°C.

[http://www.enviropedia.org.uk/Climate\\_Change/Greenhouse\\_Effect.php](http://www.enviropedia.org.uk/Climate_Change/Greenhouse_Effect.php)

### **University of Alaska-Fairbanks, Physics Department**

Greenhouse gases act as a blanket. Some of you may wonder how a green house takes solar energy and turns it into thermal energy. A good example of this is something you can observe every day in the summer in you own car. It happens when you leave you car in a sunny parking lot with the windows up. The solar energy is passing through the glass and is heating the cars interior. What's really happening is the short wave infrared waves are going in and are turning into long wave infrared waves, which cannot escape.

[http://ffden-2.phys.uaf.edu/102spring2002\\_Web\\_projects/C.Levit/web%20page.html](http://ffden-2.phys.uaf.edu/102spring2002_Web_projects/C.Levit/web%20page.html)

### **Climate.org**

Fortunately, much of this infrared radiation is absorbed in the atmosphere by the so-called greenhouse gases, making the world much warmer than it would be without them. These gases act rather like the glass in a greenhouse, which allows sunlight to enter, provides shelter from the wind and prevents most of the infrared energy from escaping, keeping the temperature warm.

<http://www.climate.org.ua/ghg/ghgeffect.html>

### **State of Utah Office of Education**

On a global scale, carbon dioxide, water vapor, and other gases present in the atmosphere are similar to the glass in a greenhouse. Ultraviolet radiation from the sun (having a short wavelength) can pass through the glass. Once inside the greenhouse, the ultraviolet radiation is absorbed by soils, plants, and other objects. Upon absorption, it becomes infrared radiation or heat energy having a shorter wavelength. Because of this, infrared radiation cannot escape through the windows. The windows act like a large blanket in which they reradiate the infrared energy back into the greenhouse. This phenomenon naturally causes the overall temperature within the greenhouse to increase.

[http://www.usoe.k12.ut.us/curr/science/core/earth/sciber9/Stand\\_6/html/1e.htm](http://www.usoe.k12.ut.us/curr/science/core/earth/sciber9/Stand_6/html/1e.htm)

### **G.H.P. Dharmaratna, Director General Department of Meteorology**

In order to understand the greenhouse effect on earth a good place to start is in a greenhouse. A greenhouse is kept warm because energy coming in from the sun (in the form of visible sunlight) is able to pass easily through the glass of the greenhouse and heat the soil and plants inside. But energy which is emitted from the soil and plants is in the form of invisible infrared radiation; this is not able to pass as easily through the glass of the greenhouse. Some of the infrared heat energy is trapped inside; this is the main reason why a greenhouse is warmer than outside.

<http://www.lankajalani.org/Publications/Paper%20-%20Impacts%20of%20Climate%20Change.doc>

### **Weather-Climate.org**

This warming effect is called the "greenhouse effect" because it is the same process as that which occurs in a greenhouse on a sunny day. The glass is transparent to short-wave radiation but absorbs the outgoing long-wave radiation, causing a rise in temperature inside the greenhouse.

<http://www.weather-climate.org.uk/04.php>

### **NASA**

There are many greenhouse gases, but the most abundant greenhouse gases are water vapor and carbon dioxide. Shortwave radiation from the sun passes through greenhouse gases, but longwave radiation is absorbed by them.

Greenhouse gases absorb longwave radiation that is emitted by the surface of the earth. Subsequently, they re-emit the energy as longwave radiation in all directions. About half of the re-emitted longwave radiation does escape into space, and contributes to the planet's radiative equilibrium.

About half of the longwave radiation emitted by the gases is directed back toward the surface of the earth. As a result, a continual exchange of longwave radiation takes place between the surface of the earth and the atmosphere above it.

The longwave radiation contained in this exchange causes the warming effect known as the greenhouse effect.

This phenomenon is known as the greenhouse effect because, like the glass on a greenhouse, the atmosphere traps some of the energy beneath it.

[http://earthobservatory.nasa.gov/Laboratory/PlanetEarthScience/GlobalWarming/GW\\_Movie3.html](http://earthobservatory.nasa.gov/Laboratory/PlanetEarthScience/GlobalWarming/GW_Movie3.html)

### **National Oceanic and Atmospheric Administration (NOAA)**

What is the Greenhouse Effect?

The glass walls and roof of a greenhouse allow most of the sun's light in, but do not allow most of the heat to escape. This causes the temperature inside the greenhouse to be warmer than outside. The earth's atmosphere, and in particular carbon dioxide (CO<sub>2</sub>) and water vapor (H<sub>2</sub>O), acts like a greenhouse, trapping heat and making the earth warmer.

<http://wdc.obs-mip.fr/globalwarming/greeneffect.html>

### **National Oceanic and Atmospheric Administration (NOAA)**

The greenhouse effect occurs when the atmosphere of a planet acts much like the glass in a greenhouse. Like the greenhouse glass, the atmosphere allows visible solar energy to pass through, but it also prevents some energy from radiating back out into space. The greenhouse effect insures that the surface of a planet is much warmer than interplanetary space because the atmosphere traps heat in the same way a greenhouse traps heat. Certain gases in our atmosphere, called greenhouse gases, tend to reflect radiant energy from the Earth's atmosphere back to the Earth's surface, improving the atmosphere's ability to trap heat.

<http://www.fsl.noaa.gov/outreach/education/sam1/Activity5.html>

### **National Oceanic and Atmospheric Administration (NOAA)**

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[http://www.fsl.noaa.gov/outreach/education/samii/SAMII\\_Act6.pdf](http://www.fsl.noaa.gov/outreach/education/samii/SAMII_Act6.pdf)

### **Draft of IPCC Fourth Assessment Report**

The name "greenhouse effect" comes from the analogy with a greenhouse made of glass which allows sunlight to enter but restricts infrared energy from leaving, thus warming the interior.

[...] The natural greenhouse effect is neither harmful nor mysterious. Its basic principles are well-understood and are firmly based on fundamental physics.

[http://ipcc-wg1.ucar.edu/wg1/Comments/drafts/AR4WG1\\_Ch01\\_FOD.pdf](http://ipcc-wg1.ucar.edu/wg1/Comments/drafts/AR4WG1_Ch01_FOD.pdf)

### **Hunan University, China**

- Light from the sun includes the entire visible region and smaller portions of the adjacent UV and infrared regions.
- Sunlight penetrates the atmosphere and warms the earth's surface.
- Longer wavelength infrared radiation is radiated from the earth's surface.
- A considerable amount of the outgoing IR radiation is absorbed by gases in the atmosphere and reradiated back to earth.

The gases in the atmosphere that act like glass in a greenhouse are called greenhouse gases.

<http://jpkc.lzjtu.edu.cn/hjhx/jpkc/7.ppt>

### **The Public Broadcasting Service**

In part, we owe our existence to a process called the greenhouse effect. Inside an artificial greenhouse filled with plants, the surrounding glass traps the sun's energy, making it warm inside, even while outside the temperature may be much colder. This same effect happens every day on the Earth. Gases within the atmosphere act like glass, trapping the sun's heat.

<http://www.pbs.org/wgbh/nova/ice/greenhouse.html>

### **BBC**

A greenhouse works because of the glass panels that line the roof and walls. The glass is transparent to the visible light from the sun, so sunlight can shine in and warm things inside the greenhouse. Now a body at about 35°C emits mostly infrared radiation. (On the other hand our sun, with a surface temperature of about 5500°C, emits mostly visible light.) The glass panels are opaque to infrared light. The result is that the glass lets the energy of the sun in, but won't let it back out. This keeps the inside of a greenhouse warm.

Replace the greenhouse with Earth and glass panels with atmosphere in the above example, and that is how the Earth's greenhouse effect works.

<http://www.bbc.co.uk/dna/h2g2/A283277>

### **University Corporation for Atmospheric Research (UCAR)**

Have you ever been inside a greenhouse on a cold winter day? It might be cold outside, but inside the greenhouse lush green plants flourish in the warmth and sunshine. Greenhouses are made of glass and are designed to hold heat inside. The atmospheres of some planets are able to trap energy just like a greenhouse. Energy from the Sun can enter the atmosphere, but not all of it can easily find its way out again.

What blocks the Sun's energy from escaping a planet's atmosphere? Unlike a greenhouse, planets do not have a layer of glass over them! Instead, molecules in the atmosphere called greenhouse gases absorb the heat.

[http://www.windows.ucar.edu/tour/link=/earth/interior/greenhouse\\_effect.html](http://www.windows.ucar.edu/tour/link=/earth/interior/greenhouse_effect.html)

### **University of Michigan**

The "greenhouse effect" is the heating of the Earth due to the presence of greenhouse gases. It is named this way because of a similar effect produced by the glass panes of a greenhouse. Shorter-wavelength solar radiation from the sun passes through Earth's atmosphere, then is absorbed by the surface of the Earth, causing it to warm. Part of the absorbed energy is then reradiated back to the atmosphere as long wave infrared radiation. Little of this long wave radiation escapes back into space; the radiation cannot pass through the greenhouse gases in the atmosphere. The greenhouse gases selectively transmit the infrared waves, trapping some and allowing some to pass through into space. The greenhouse gases absorb these waves and reemits the waves downward, causing the lower atmosphere to warm.

<http://www.umich.edu/~gs265/society/greenhouse.htm>

### **Cary Academy, North Carolina**

The term "greenhouse effect" describes how the gasses in Earth's atmosphere retain the radiant energy from the sun instead of letting it fly back out into space. The glass of the greenhouse works the same way.

In short, the gasses in the atmosphere let energy in and don't let all the energy back out.

[http://web1.caryacademy.org/chemistry/rushin/StudentProjects/CompoundWebSites/2000/CarbonDioxide/greenhouse\\_effect.htm](http://web1.caryacademy.org/chemistry/rushin/StudentProjects/CompoundWebSites/2000/CarbonDioxide/greenhouse_effect.htm)

## **Appalachian State University, North Carolina**

Selective Absorbers and Greenhouse Effect.

Our atmosphere is a selective filter since it is transparent to some wavelengths and absorbs others.

The greenhouse effect occurs when the energy absorbed is not all be radiated because of the filtering of the atmosphere. Some of the earth's radiated energy is reflected back to the surface. Consequently the earth's atmosphere has an increased temperature. This process is much like the action of glass in a greenhouse.

<http://www.physics.appstate.edu/courses/FirstExamReview.rtf>

## **The University of Colorado at Colorado Springs**

3. greenhouse effect

a. transmission can depend on wavelength of radiation

b. glass

1) readily transmits shortwave radiation but not longwave radiation

2) that's why heat builds up in a closed automobile

c. greenhouse effect: the trapping of heat in the lower troposphere because of differential transmissivity for short and long waves

1) greenhouse gases readily transmit incoming shortwave radiation from the sun but do not easily transmit outgoing longwave terrestrial radiation

2) most important greenhouse gases: water vapor and CO<sub>2</sub>

3) terrestrial radiation is absorbed by greenhouse gases and reradiated back toward the surface

<http://web.uccs.edu/geogenvs/ges100-online/Chapt4.doc>

## **Nathan Phillips, Associate Professor, Geography and Environment**

### **Boston University**

A simple greenhouse effect model

A. Glass represents the 'normal' greenhouse effect on earth and is at top of atmosphere

B. Solar shortwave radiation  $S$  largely makes it to surface

C. For energy balance, top of glass must send  $S$  back out

D. Greenhouse gases don't have a preferred direction; they send  $S$  units in both directions – up and down

E. Thus, the surface of the earth receives  $2S$  due to the greenhouse effect – instead of  $1S$  if there were no atmosphere!

G. Thermal radiation emitted from earth =  $2S$

[http://people.bu.edu/nathan/ge510\\_06\\_6.pdf](http://people.bu.edu/nathan/ge510_06_6.pdf)

## **ThinkQuest Education Foundation**

In a greenhouse, heat from the sun enters the glass. The heat in the form of infra-red light bounces and heads back up towards the glass. The glass then allows only some of this heat to escape, but reflects back another portion. This heat remains bouncing within the greenhouse. In the case of planet Earth, there is no glass, but there is an atmosphere which retains heat or releases heat.

<http://library.thinkquest.org/11353/greenhouse.htm>

## **Moorland School, Earth Science (UK)**

Imagine that Earth has been encircled by a giant glass sphere. The heat of the sun penetrates through the glass. Some of the heat is absorbed by the Earth, and some of it is radiated back towards space. The radiated heat reaches the glass sphere and is prevented from dispersing any further.

Similarly, the earth is surrounded by a blanket of gases. This blanket traps energy in the atmosphere, much the same way as glass traps heat inside a greenhouse. This results in an

accumulation of energy, and the overall warming of the atmosphere. The 'greenhouse effect' is the popular expression for the above process.

<http://www.moorlandschool.co.uk/earth/greenhou.htm>

### **Eli Rabett**

What happens in a greenhouse is the same mechanism that heats a car up when you close the windows. The sun's light (radiation) shines through the glass. The light energy checks in, but it can't get out because both air flow (most important) and conduction are closed off. The fancy name for air flow is convection. We might fall into the habit of using that below.

That leaves radiation. The wavelength of radiation emitted from a surface depends on the temperature of the surface according to a formula first derived by Max Planck. It turns out that the emission from the sun is peaked in the green which can pass through the glass windows, but the radiation from surfaces at 300 C is peaked at much longer wavelengths in the infrared (IR), which is absorbed by the glass.

The IR radiation inside the car can heat the air inside the car, but, because it is adsorbed by the glass windows and the metal, it cannot get out.

<http://rabett.blogspot.com/2005/10/people-who-tell-you-that-greenhouse.html>

### **Grandview High School, Missouri**

Have you ever walked through a green house in late January? The temperature on the outside may have been quite cold but the temperature on the inside might have felt almost balmy!

This is not because of a giant furnace located in the back of the green house, but because of the green house effect. When rays from the sun travel through the glass, it strikes all materials within the greenhouse. Because of this, the objects will heat up as does everything that comes in contact with the suns infrared rays (heat). These rays generally bounce back towards where they came from unless there is a barrier to keep them in. Yes that's right, a barrier such as glass!

#### *The Green House Effect*

Once the infrared rays bounce off of the objects contained in the green house, some of the rays get trapped inside of the greenhouse because of the glass. The rays then bounce off of the glass and back towards all of the objects in the green house. As the rays of infrared radiation (found in sunlight) bounce all over the greenhouse, the greenhouse heats up.

<http://www.csd4.k12.mo.us/egits/MAP%20TAP/Andy%20Leech/greenhouse.ppt>

### **Science Encyclopedia**

The greenhouse effect is the retention by the Earth's atmosphere in the form of heat some of the energy that arrives from the Sun as light. Certain gases, including carbon dioxide (CO<sub>2</sub>) and methane (CH<sub>4</sub>), are transparent to most of the wavelengths of light arriving from the Sun but are relatively opaque to infrared or heat radiation; thus, energy passes through the Earth's atmosphere on arrival, is converted to heat by absorption at the surface and in the atmosphere, and is not easily re-radiated into space. The same process is used to heat a solar greenhouse, only with glass, rather than gas, as the heat-trapping material.

<http://science.jrank.org/pages/3148/Greenhouse-Effect.html>

### **California Environmental Protection Agency**

Simply put, the greenhouse effect compares the earth and the atmosphere surrounding it to a greenhouse with glass panes. Plants in a greenhouse thrive because the glass panes keep the air inside at a fairly even temperature day and night, and throughout the four seasons of the year. Just as the glass lets heat from sunlight in and reduces the heat escaping, greenhouse gases and some particles in the atmosphere keep the Earth at a relatively even temperature.

<http://www.arb.ca.gov/cc/factsheets/ccbackground.pdf>

### **The Atmosphere, Climate & Environment (ACE) Information Programme (UK)**

The greenhouse gases in the atmosphere act in a similar way to panes of glass in a greenhouse (see Figure 2 below). Radiation from the Sun (consisting mainly of visible and ultraviolet (UV) radiation) can travel through glass into the greenhouse. When this radiation is absorbed by objects in the greenhouse, it is re-radiated as infrared (IR) radiation, or heat. This heat cannot escape through the glass, so the greenhouse warms.

up.[http://www.ace.mmu.ac.uk/Resources/Teaching\\_Packs/Key\\_Stage\\_4/Climate\\_Change/01p.html](http://www.ace.mmu.ac.uk/Resources/Teaching_Packs/Key_Stage_4/Climate_Change/01p.html)

### **The University of Winnipeg**

As glass in a greenhouse traps heat inside, gases in the upper atmosphere trap some of the heat escaping the Earth, creating a greenhouse effect.

[http://theory.uwinnipeg.ca/mod\\_tech/node204.html](http://theory.uwinnipeg.ca/mod_tech/node204.html)

### **The University of the Western Cape, South Africa**

A greenhouse is made entirely of glass. When sunlight (shortwave radiation) strikes the glass, most of it passes through and warms up the plants, soil and air inside the greenhouse. As these objects warm up they give off heat, but these heat waves have a much longer wavelength than the incoming rays from the sun. This longwave radiation cannot easily pass through glass, it is re-radiated into the greenhouse, causing everything in it to heat up.

<http://www.botany.uwc.ac.za/envfacts/facts/gwarming.htm>

### **Department of Environmental Affairs and Tourism, South Africa**

Energy coming from the sun passes through the atmosphere and warms the Earth - but the emitted infra-red radiation coming from the Earth's surface is partly absorbed by gases in the atmosphere and some of it is re-emitted downwards, further warming the surface of the Earth and the lower levels of the atmosphere. This effect has been called the 'greenhouse effect' because of a similar effect caused by glass in a greenhouse: it lets sunlight into the greenhouse but in turn traps a portion of infra-red radiation (heat) inside the greenhouse.

[http://www.environment.gov.za/ClimateChange2005/Greenhouse\\_Gases\\_and\\_the\\_Greenhouse\\_Effect.htm](http://www.environment.gov.za/ClimateChange2005/Greenhouse_Gases_and_the_Greenhouse_Effect.htm)

### **U.S. Department of the Interior, U.S. Geological Survey**

The gases that encircle the Earth allow some of this heat to escape into space, but absorb some and reflect another portion back to the Earth. The process is similar in Mountain View, only, the greenhouse there is made of glass instead of gas.

[http://hvo.wr.usgs.gov/volcanowatch/1998/98\\_10\\_22.html](http://hvo.wr.usgs.gov/volcanowatch/1998/98_10_22.html)

### **The Institute for Educational Technology, Italy**

Just as it happens in a greenhouse where the function carbon dioxide performs in the atmosphere is played by glass-rafters, the sun's energy arrives down at the earth, where it is partially absorbed and partially reflected. Such reflected heat, however, is reflected again, by glass as for the greenhouse, by carbon dioxide as for the atmosphere, down on earth: it is as if a part of the heat were entrapped, thus determining a growth of temperature on the ground.

[http://www.itd.cnr.it/ge8/rivista/inglese/num\\_2/galil3.htm](http://www.itd.cnr.it/ge8/rivista/inglese/num_2/galil3.htm)

### **University of Cincinnati College of Engineering, Ohio**

Greenhouses are much warmer inside than the air is outside because the glass is transparent to light and allows short-wavelength light to pass through and heat the contents of the greenhouse. It also reflects back the longer wavelength heat radiating within the greenhouse, thus preventing it from passing back out.

In a glass greenhouse, heat builds up and gets trapped due to presence of carbon dioxide and other heat trapping gases in the upper atmosphere. CO<sub>2</sub> is analogous to glass.

<http://www.eng.uc.edu/~pbishop/Chapter-3-Slides.ppt>

### **Miami-Dade Environmental Resources Department, Florida**

The phenomenon gets its name from the similarity to a garden greenhouse. Visible light passes through the glass ceiling and walls of a greenhouse. Some of the light is absorbed, some is reflected back, and a portion of it is radiated out as heat. Glass, like carbon dioxide (CO<sub>2</sub>) and other "greenhouse gases" doesn't allow heat to escape back out.

[http://www.miamidade.gov/derm/climate\\_change\\_greenhouse\\_effect.asp](http://www.miamidade.gov/derm/climate_change_greenhouse_effect.asp)

### **University of Washington, School of Oceanography**

Greenhouse effect: a blanket of water vapor and CO<sub>2</sub> and methane CH<sub>4</sub> traps the upward infra-red 'long-wave' or 'heat' radiation. The pane-of-glass model assumes total absorption of upward infrared waves yet no absorption of visible light..both of which are not completely accurate, hence the numbers are not applicable to the real atmosphere, yet demonstrate the effect.

— incoming solar radiation,  $I$  in watts/meter<sup>2</sup>

— some is simply reflected back to space the rest is absorbed by ocean and land and atmosphere yet re-radiated as infrared heat, both upward and downward (red arrows)

— The net effect of the 'blanket' of atmosphere is to have more downward radiation toward the Earth's surface than just the incident sunlight.

[http://www.ocean.washington.edu/courses/as222d/lecture2\(6\)-slides07.pdf](http://www.ocean.washington.edu/courses/as222d/lecture2(6)-slides07.pdf)

### **Saskatchewan Schools and School Divisions, Canada**

The heat-trapping gases in the atmosphere behave like the glass of a greenhouse. They let much of the Sun's rays in, but keep most of that heat from directly escaping. This is why they are called greenhouse gases. Without these gases, heat energy absorbed and reflected from the Earth's surface would easily radiate back out to space, leaving the planet with an inhospitable temperature close to -19°C (2°F), instead of the present average surface temperature of 15°C (59°F).

[http://www.saskschools.ca/~greenall/scienceprojects/greenhouse\\_effect.htm](http://www.saskschools.ca/~greenall/scienceprojects/greenhouse_effect.htm)

### **U.S. House of Representatives Select Committee on Energy Independence and Global Warming**

Just like the glass of a greenhouse traps warm air inside, certain gases in the atmosphere trap heat that would otherwise escape into space.

<http://globalwarming.house.gov/issues/globalwarming?id=0002>

### **The Austrian JI/CDM- Programme**

The Earth's atmosphere is comparable to a glass roof of a greenhouse: the short-wave solar radiation passes through nearly unhindered and warms the Earth's surface. From the Earth's surface, the short-wave radiation is partly absorbed and partly reflected back as long-wave thermal radiation. However, this long-wave thermal radiation cannot pass the atmosphere unhindered due to the greenhouse gases but is partly reflected back again to the Earth's surface. In absence of this natural greenhouse effect the average temperature on the Earth would not reach the present level of about plus 15 degrees Celsius, but about minus 18 degrees Celsius.

<http://www.ji-cdm-austria.at/en/portal/kyotoandclimatechange/ourclimate/greenhouseeffect/>

**Torfaen County, Environment and Planning, Wales**

Some of the energy from the sun is trapped inside our atmosphere as it is reflected back from the earth towards space. This natural process is called the greenhouse effect, as the atmosphere acts like the glass walls of a greenhouse, which allows the sun's rays to enter but keeps the heat in.

<http://www.torfaen.gov.uk/EnvironmentAndPlanning/EnergyEfficiencyAdviceAndAssessment/ClimateChange/GreenhouseEffect.aspx>

**Fort Lewis College, Physics Department, Colorado**

This partial trapping of solar radiation is known as the greenhouse effect. The name comes from the fact that a very similar process operates in a greenhouse. Sunlight passes relatively unhindered through glass panes, but much of the infrared radiation reemitted by the plants is blocked by the glass and cannot get out. Consequently, the interior of the greenhouse heats up, and flowers, fruits, and vegetables can grow even on cold wintry days.

<http://physics.fortlewis.edu/Astronomy/astronomy%20today/CHAISSON/AT307/HTML/AT30702.HTM>

**The National Assessment Synthesis Team, US Global Change Research Program**

The composition of the atmosphere is particularly important because certain gases (including water vapor, carbon dioxide, methane, halocarbons, ozone, and nitrous oxide) absorb heat radiated from the Earth's surface. As the atmosphere warms, it in turn radiates heat back to the surface, to create what is commonly called the "greenhouse effect."

<http://www.usgcrp.gov/usgcrp/Library/nationalassessment/overviewclimate.htm>

**Eduhistory.com**

The glass used for a greenhouse acts as a selective transmission medium for different spectral frequencies, and its effect is to trap energy within the greenhouse, which heats both the plants and the ground inside it. This warms the air near the ground, and this air is prevented from rising and flowing away. This can be demonstrated by opening a small window near the roof of a greenhouse: the temperature drops considerably. Greenhouses thus work by trapping electromagnetic radiation and preventing convection.

<http://www.eduhistory.com/greenhouse.htm>

**Northwestern University, Evanston, Illinois**

Overview: Carbon Dioxide is identified as "greenhouse gas" because of its ability to trap heat within earth's environment. ...Explain that the greenhouse effect works in a somewhat similar -- but not entirely the same -- way (see teacher notes and background supplement sheet for more information). The sun's rays pass through the atmosphere and warm the surface. The earth emits some of this energy back into space (like heat from a campfire). But gases such as carbon dioxide and water vapor (in clouds) absorb much of this energy and send it back to earth. People have come to call this process the "greenhouse effect" because it reminds them of how actual greenhouses, which are made out of glass and grow plants, let the sun's rays in while trapping much of the radiation that would otherwise escape.

<http://www.letus.northwestern.edu/projects/gw/pdf/C09.pdf>

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