Materialistic Media Metrics

(God's hand taken from: The Creation of Adam, Michelangelo 1511)

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Version hints: calculations checked by Dr. Niko Ernsting, Humboldt-Universität Berlin

Purpose of this document

How much lignite coal briquettes are needed to produce the electrical power for all views of the movie trailer "Avatar" by James Cameron (2009) on YouTube[1]? This amount of coal will be piled into an installation called " Avatar[2]", creating the avatar of the film's online video trailer as a massive body of lignite coal briquettes.

***Note**: numbers in this document use German notation (i.e. 1.000.000,00 for one million).*

Avatar Trailer The Movie (New Extended HD Trailer)

On October 29, 2009, just after the release of the online movie trailer it quickly hit one million views, which is the basis for the following calculations.

File sizes

The video is offered in 3 formats on the website:

- 360p with a file size of 22.494.948 bytes
- 480p with a file size of 33.248.882 bytes (default)
- 720p with a file size of 57.458.788 bytes (HD)

Assuming an equal distribution over all views we get an average file size of 37.734.206 bytes for one video file.

37.734 TCP packets are needed to transmit the file over the network. Since each TCP packet has an overhead of around 40 bytes, the complete TCP overhead amounts to 1.509.368 bytes. Therefore, the total amount of bytes transmitted for one video file is 39.243.574 bytes.

The containing web page with all additional elements (except the video) has a file size of 628.308 bytes (HTML, CSS, JavaScript, SWF and pictures). This web page loads once for each view.

1 http://www.YouTube.com/watch?v=cRdxXPV9GNQ
2 http://m-pire.com/avatar.php

Views

On October 29, 2009, the web page registered 1 million views. As the views policy of YouTube is not transparent and is subject to change over time[3], we assume, that only 33% of all views count as full views. That means that the total number of bytes transmitted for all assumed full views for the video files amounts to 12.950.379.499.200 bytes.

The amount of bytes transmitted for 1 million loadings of the containing web pages amount to 628.308.000.000 bytes (regardless whether the video is fully viewed or not).
Therefore, the total sum of bytes transmitted for all full views of the video files including the web page amounts to 13.578.687.499.200 bytes or roughly 12,35 Terabytes.

The energy used over the Internet

To calculate the amount of energy needed to transmit these bytes over the internet is a monumental task. We refer to the research of Jonathan G. Koomey[4], Ph.D., Project Scientist, Lawrence Berkeley National Laboratory and Consulting Professor, Department of Civil and Environmental Engineering, Stanford University, who was so kind to share his results[5] with us. As Mr. Koomey points out, we need 3,5 kWh of energy to transmit 1 Gigabyte of data over the internet in 2010. As a result we need **44.261 kWh** to transmit 12,35 Terabytes over the internet.

The energy used at home

The duration of the "Avatar" video trailer is 219 seconds (3:39 minutes). Assuming 33% full views, we get a total duration for all full views at home of 72.270.000 seconds or 20.075 hours (roughly 2,29 years).
We assume that 50% of all views at home were done on laptops and 50% on desktop computers. Assuming that a laptop has a power consumption of 30 W and a desktop PC including monitor of 130 W, we get an average consumption per computer of 80 W. As a result we will need 1.606 kWh for all full views at home.

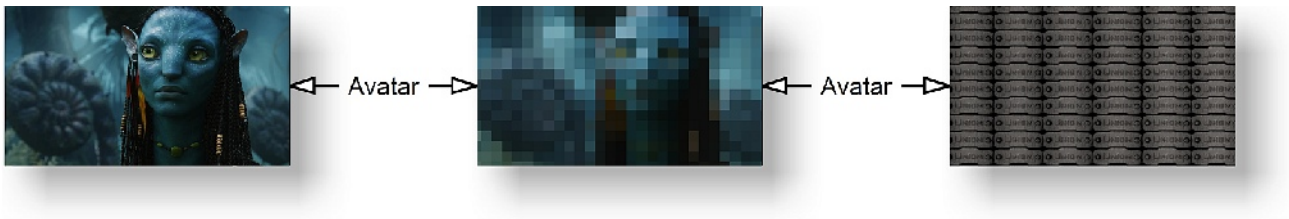
Considering the embedded energy needed for the production of all these laptops and desktop PC's we take the following assumptions:

- Energy required to produce a computer: 1.778 kWh
- Lifespan of a computer: 6 years
- Hours of usage per day: 4 hours

Therefore a computer is used 8.760 hours during its total lifespan and the embedded energy cost for 1 hour of usage amounts to 0,203 kWh.
The embedded energy cost for watching the trailer for above 20.075 hours amounts to a total of 4.075 kWh[6]. Therefore, we need a total of **5.681 kWh** for watching the video trailer at home.

Summing up both values for the energy cost over the internet and viewing at home we get a total of **49.942 kWh**.

3 http://www.tubemogul.com/research/report/6
4 Taylor, Cody, and Jonathan Koomey. 2008. Estimating energy use and greenhouse gas emissions of Internet advertising. Working paper for IMC2. February 14. http://imc2.com/Documents/CarbonEmissions.pdf
5 Since all calculations were done in 2006, Mr. Koomey pointed out, that we need to extend the trend of halving electricity intensity every 2 years and chop the 2008 intensity in half to get to a reasonable value for the year 2010. This is due to the increasing efficiency of all devices operating the internet.
6 Since we do not know the energy cost for dumping and recycling a computer, we will not include it in our calculation.



Lignite Coal Briquettes

A lignite briquette has the following specifications[7]:

- Length: 0,180 m
- Depth: 0,060 m
- Height: 0,045 m
- Weight: 0,5682 kg
- Calorific value per kg: 19,80 MJ or 5,50 kWh

Therefore the volume of a lignite briquette is 0,000486 m^3 and the calorific value 3,13 kWh.

Energy conversion

The process of energy conversion involves loss. For instance, by burning the coal, first the heat corresponding to this chemical reaction (calorific value) is produced. Boiling water with this heat converts the thermal energy into kinetic energy (steam) which is then transformed into mechanical energy by driving a turbine. As an ultimate output this mechanical energy is converted into electrical energy. The maximum efficiency of converting the heat-of-combustion from lignite coal into electrical energy is 43% in a very modern power plant.
Mining coal needs electrical power itself and therefore has an efficiency of 60%. Distributing energy over power lines has an efficiency of 95% due to transmission losses and electrical resistance.

Multiplying these values, we find that total efficiency of coal from mining to site electricity amounts to 25%.

One lignite briquette can therefore generate 0,766 kWh of electrical power from its inherent calorific value of 3,13 kWh.

7 http://www.heizprofi.com/content_manager/page.php?ID=17161&edbc_modul=prodkatalog&edbc_view=detail_prodkatalog&edbc_parent=3377&edbc_ID=3306&dbc=365bfb77bb98b38dc3ea9c32feea5ea8

Result

For generating the electrical energy of 49.942 kWh to serve, transmit and view the "Avatar" video trailer 1 million times on YouTube we will need an estimated total of:

- 65.202 lignite briquettes with a
- volume of 31,69 m^3 and a
- weight of 37 tons releasing
- 54 tons of CO_2 into the atmosphere

This amount of lignite briquettes can be represented by

- a massive cube with an edge length of 3,16 m
- a monolith (aspect 1:4:9) measuring 0,96 m * 3,83 m * 8,63 m
- a pyramid (aspect like Giza) with a base side of 5,31 m and a height of 3,38 m
- a line of briquettes with the length of 11,74 km
- a briquette square with a side length of 26,46 m

$E=mc^2$

Would there be a power plant with an efficiency of 100% to convert mass directly into energy, we would need the following amount of mass to create electrical energy for our views:

- 2,00 milligrams of mass, which is the same weight as 2/1000 of a milliliter of water, or a tiny drop

Growth

Our cube of Lignite Briquettes is growing. As of June 1st, 2010, the total views for the trailer have surpassed 14.5 million creating a cube with the side length of 7 meters, weighing 540 tons. The cube is continuously growing and hence so is the amount of coal physically burnt in exchange.

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These 14.584.515,00 views need the:

- total energy of 728.380,83 kWh
- being a total of 950.935,97 lignite briquette units
- having a total volume of 462,15 m^3
- a weight of 540.321,82 kg
- releasing 786.651,29 kg CO2 into the atmosphere

This amount of Lignite Briquettes can be represented by

- a massive cube with an edge length of 7,73 m
- a monolith (aspect 1:4:9) measuring 2,34 m * 9,37 m * 21,07 m
- a pyramid (aspect like Giza) with a base side of 12,96 m and a height of 8,25 m
- a line of briquettes with the length of 171 km
- a one briquette unit high square with a side length of 101,34 m

Using E=mc2 we would merely need

- 29,18 milligrams of mass for producing these 728.380,83 kWh