

# Society & Electronics



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Chapter- 1

# Mobile Phone Radiation and Health



A Greenfield-type tower used in base stations for mobile telephony

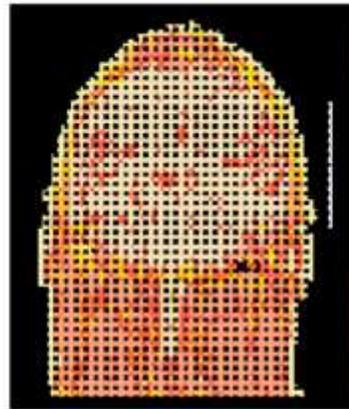
The effect mobile phone radiation has on human health is the subject of recent interest and study, as a result of the enormous increase in mobile phone usage throughout the world (as of June 2009, there were more than 4.3 billion users worldwide). Mobile phones use electromagnetic radiation in the microwave range, which some believe may be harmful to human health. A large body of research exists, both epidemiological and experimental, in non-human animals and in humans, of which the majority shows no definite causative relationship between exposure to mobile phones and harmful biological effects in humans. This is often paraphrased simply as the balance of evidence showing no harm to humans from mobile phones, although a significant number of individual studies do suggest such a relationship, or are inconclusive. Other digital wireless systems, such as data communication networks, produce similar radiation.

The World Health Organization, based upon the majority view of scientific and medical communities, has stated that cancer is unlikely to be caused by cellular phones or their base stations and that reviews have found no convincing evidence for other health effects. The WHO expects to make recommendations about mobile phones in 2010. Some national radiation advisory authorities have recommended measures to minimize exposure to their citizens as a precautionary approach.

## **Effects**

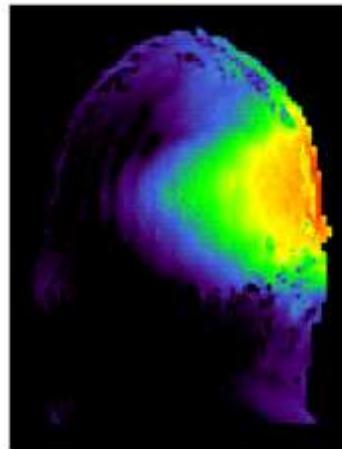
Many scientific studies have investigated possible health effects of mobile phone radiations. These studies are occasionally reviewed by some scientific committees to assess overall risks. A recent assessment was published in 2007 by the European Commission Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR). It concludes that the three lines of evidence, *viz.* animal, *in vitro*, and epidemiological studies, indicate that "exposure to RF fields is unlikely to lead to an increase in cancer in humans."

## **Radiation absorption**



Voxel size =  
1.0x1.0x1.0 mm

Tissues: muscle &  
high water content  
tissue-light red, fat  
and bone-dark yellow,  
blood-dark red, brain  
-light yellow, skin-ligh  
yellow



Radiated power  
from antenna =  
125 mW

0 db = 9.50 W/kg

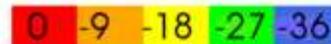


Figure 5a. Geometry of (top) and SAR distribution in phantom human head model exposed to 1900 Mhz dipole antenna.

Calculated specific absorbed radiation (SAR) distribution in an anatomical model of head next to a 125 mW dipole antenna. Peak SAR is 9.5 W/kg averaged over a 1 mg cube. (USAF/AFRL).

Part of the radio waves emitted by a mobile telephone handset are absorbed by the human head. The radio waves emitted by a GSM handset can have a peak power of 2 watts, and a US analogue phone had a maximum transmit power of 3.6 watts. Other digital mobile technologies, such as CDMA2000 and D-AMPS, use lower output power, typically below 1 watt. The maximum power output from a mobile phone is regulated by the mobile phone standard and by the regulatory agencies in each country. In most systems the cellphone and the base station check reception quality and signal strength and the power level is increased or decreased automatically, within a certain span, to accommodate different situations, such as inside or outside of buildings and vehicles. The

rate at which radiation is absorbed by the human body is measured by the Specific Absorption Rate (SAR), and its maximum levels for modern handsets have been set by governmental regulating agencies in many countries. In the USA, the Federal Communications Commission (FCC) has set a SAR limit of 1.6 W/kg, averaged over a volume of 1 gram of tissue, for the head. In Europe, the limit is 2 W/kg, averaged over a volume of 10 grams of tissue. SAR values are heavily dependent on the size of the averaging volume. Without information about the averaging volume used, comparisons between different measurements cannot be made. Thus, the European 10-gram ratings should be compared among themselves, and the American 1-gram ratings should only be compared among themselves. SAR data for specific mobile phones, along with other useful information, can be found directly on manufacturers' websites, as well as on third party web sites.

### **Thermal effects**

One well-understood effect of microwave radiation is dielectric heating, in which any dielectric material (such as living tissue) is heated by rotations of polar molecules induced by the electromagnetic field. In the case of a person using a cell phone, most of the heating effect will occur at the surface of the head, causing its temperature to increase by a fraction of a degree. In this case, the level of temperature increase is an order of magnitude less than that obtained during the exposure of the head to direct sunlight. The brain's blood circulation is capable of disposing of excess heat by increasing local blood flow. However, the cornea of the eye does not have this temperature regulation mechanism and exposure of 2–3 hours duration has been reported to produce cataracts in rabbits' eyes at SAR values from 100-140W/kg, which produced lenticular temperatures of 41°C. There were no cataracts detected in the eyes of monkeys exposed under similar conditions. Premature cataracts have not been linked with cell phone use, possibly because of the lower power output of mobile phones

### **Non-thermal effects**

The communications protocols used by mobile phones often result in low-frequency pulsing of the carrier signal. Whether these modulations have biological significance has been subject to debate.

Some researchers have argued that so-called "non-thermal effects" could be reinterpreted as a normal cellular response to an increase in temperature. The German biophysicist Roland Glaser, for example, has argued that there are several thermoreceptor molecules in cells, and that they activate a cascade of second and third messenger systems, gene expression mechanisms and production of heat shock proteins in order to defend the cell against metabolic cell stress caused by heat. The increases in temperature that cause these changes are too small to be detected by studies such as REFLEX, which base their whole argument on the apparent stability of thermal equilibrium in their cell cultures.

Other researchers believe the stress proteins are unrelated to thermal effects, since they occur for both extremely low frequencies (ELF) and radio frequencies (RF), which have very different energy levels.

### **Blood-brain barrier effects**

Swedish researchers from Lund University (Salford, Brun, Perrson, Eberhardt, and Malmgren) have studied the effects of microwave radiation on the rat brain. They found a leakage of albumin into the brain via a permeated blood-brain barrier. This confirms earlier work on the blood-brain barrier by Allan Frey, Oscar and Hawkins, and Albert and Kerns. Other groups have not confirmed these findings in cell or animal studies.

### **Cancer**

In 2006 a large Danish study about the connection between mobile phone use and cancer incidence was published. It followed over 420,000 Danish citizens for 20 years and showed no increased risk of cancer. The German Federal Office for Radiation Protection (BfS) considers this report inconclusive.

The following studies of long time exposure have been published:

- The 13 nation INTERPHONE project - the largest study of its kind ever undertaken - has now been published and did not find a solid link with mobile phones and brain tumours.

The *International Journal of Epidemiology* published a combined data analysis from a multi national population-based case-control study of glioma and meningioma, the most common types of brain tumour.

The authors reported the following conclusion:

Overall, no increase in risk of glioma or meningioma was observed with use of mobile phones. There were suggestions of an increased risk of glioma at the highest exposure levels, but biases and error prevent a causal interpretation. The possible effects of long-term heavy use of mobile phones require further investigation.

In the press release accompanying the release of the paper, Dr Christopher Wild, Director of the International Agency for Research on Cancer (IARC) said:

An increased risk of brain cancer is not established from the data from Interphone. However, observations at the highest level of cumulative call time and the changing patterns of mobile phone use since the period studied by Interphone, particularly in young people, mean that further investigation of mobile phone use and brain cancer risk is merited.

A number of independent health and government authorities have commented on this important study including The Australian Centre for Radiofrequency Bioeffects Research (ACRBR) which said in a statement that:

Until now there have been concerns that mobile phones were causing increases in brain tumours. Interphone is both large and rigorous enough to address this claim, and it has not provided any convincing scientific evidence of an association between mobile phone use and the development of glioma or meningioma. While the study demonstrates some weak evidence of an association with the highest tenth of cumulative call time (but only in those who started mobile phone use most recently), the authors conclude that biases and errors limit the strength of any conclusions in this group. It now seems clear that if there was an effect of mobile phone use on brain tumour risks in adults, this is likely to be too small to be detectable by even a large multinational study of the size of Interphone.

The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) which said in a statement that:

On the basis of current understanding of the relationship between brain cancer and use of mobile phones, including the recently published data from the INTERPHONE study, ARPANSA:

**concludes** that currently available data do not warrant any general recommendation to limit use of mobile phones in the adult population,

**continues** to inform those concerned about potential health effects that they may limit their exposure by reducing call time, by making calls where reception is good, by using hands-free devices or speaker options, or by texting; and

**recommends** that, due to the lack of any data relating to children and long term use of mobile phones, parents encourage their children to limit their exposure by reducing call time, by making calls where reception is good, by using hands-free devices or speaker options, or by texting.

The Cancer Council Australia said in a statement that it cautiously welcomed the results of the largest international study to date into mobile phone use, which has found no evidence that normal use of mobile phones, for a period up to 12 years, can cause brain cancer.

Chief Executive Officer, Professor Ian Olver, said findings from the Interphone study, conducted across 13 countries including Australia, were consistent with other research that had failed to find a link between mobile phones and cancer.

This supports previous research showing mobile phones don't damage cell DNA, meaning they can't cause the type of genetic mutations that develop into cancer," Professor Olver said.

However, it has been suggested that electromagnetic fields associated with mobile phones may play a role in speeding up the development of an existing cancer. The Interphone study found no evidence to support this theory.

- A Danish study (2004) that took place over 10 years found no evidence to support a link. However, this study has been criticized for collecting data from subscriptions and not necessarily from actual users. It is known that some subscribers do not use the phones themselves but provide them for family members to use. That this happens is supported by the observation that only 61% of a small sample of the subscribers reported use of mobile phones when responding to a questionnaire.
- A Swedish study (2005) that draws the conclusion that "the data do not support the hypothesis that mobile phone use is related to an increased risk of glioma or meningioma."
- A British study (2005) that draws the conclusion that "The study suggests that there is no substantial risk of acoustic neuroma in the first decade after starting mobile phone use. However, an increase in risk after longer term use or after a longer lag period could not be ruled out."
- A German study (2006) that states "In conclusion, no overall increased risk of glioma or meningioma was observed among these cellular phone users; however, for long-term cellular phone users, results need to be confirmed before firm conclusions can be drawn."
- A joint study conducted in northern Europe that draws the conclusion that "Although our results overall do not indicate an increased risk of glioma in relation to mobile phone use, the possible risk in the most heavily exposed part of the brain with long-term use needs to be explored further before firm conclusions can be drawn."

Other studies on cancer and mobile phones are:

- A Swedish scientific team at the Karolinska Institute conducted an epidemiological study (2004) that suggested that regular use of a mobile phone over a decade or more was associated with an increased risk of acoustic neuroma, a type of benign brain tumor. The increase was not noted in those who had used phones for fewer than 10 years.
- The INTERPHONE study group from Japan published the results of a study of brain tumour risk and mobile phone use. They used a new approach: determining the SAR inside a tumour by calculating the radio frequency field absorption in the exact tumour location. Cases examined included glioma, meningioma, and pituitary adenoma. They reported that the overall odds ratio (OR) was not

increased and that there was no significant trend towards an increasing OR in relation to exposure, as measured by SAR.

In 2007, Dr. Lennart Hardell, from Örebro University in Sweden, reviewed published epidemiological papers (2 cohort studies and 16 case-control studies) and found that :

- Cell phone users had an increased risk of malignant gliomas.
- Link between cell phone use and a higher rate of acoustic neuromas.
- Tumors are more likely to occur on the side of the head that the cell handset is used.
- One hour of cell phone use per day significantly increases tumor risk after ten years or more.

In a February 2008 update on the status of the INTERPHONE study IARC stated that the long term findings ‘...could either be causal or artifactual, related to differential recall between cases and controls.’

- A self-published and non-peer reviewed meta-study by Dr. Vini Khurana, an Australian neurosurgeon, presented what it termed "increasing body of evidence ... for a link between mobile phone usage and certain brain tumours" and that it "is anticipated that this danger has far broader public health ramifications than asbestos and smoking". This was criticised as ‘...an unbalanced analysis of the literature, which is also selective in support of the author’s claims.’

A publication titled "Public health implications of wireless technologies" cites that Lennart Hardell found age is a significant factor. The report repeated the finding that the use of cell phones before age 20 increased the risk of brain tumors by 5.2, compared to 1.4 for all ages. A review by Hardell et al. concluded that current mobile phones are not safe for long-term exposure.

In a time trends study in Europe, conducted by the Institute of Cancer Epidemiology in Copenhagen, no significant increase in brain tumors among cell phone users was found between the years of 1998 and 2003. "The lack of a trend change in incidence from 1998 to 2003 suggests that the induction period relating mobile phone use to brain tumors exceeds 5–10 years, the increased risk in this population is too small to be observed, the increased risk is restricted to subgroups of brain tumors or mobile phone users, or there is no increased risk."

### **Cognitive effects**

A 2009 study examined the effects of exposure to radiofrequency radiation (RFR) emitted by standard GSM cell phones on the cognitive functions of humans. The study confirmed longer (slower) response times to a spatial working memory task when exposed to RFR from a standard GSM cellular phone placed next to the head of male subjects, and showed that longer duration of exposure to RFR may increase the effects on performance. Right-handed subjects exposed to RFR on the left side of their head on

average had significantly longer response times when compared to exposure to the right side and sham-exposure.

### **Electromagnetic hypersensitivity**

Some users of mobile handsets have reported feeling several unspecific symptoms during and after its use; ranging from burning and tingling sensations in the skin of the head and extremities, fatigue, sleep disturbances, dizziness, loss of mental attention, reaction times and memory retentiveness, headaches, malaise, tachycardia (heart palpitations), to disturbances of the digestive system. Reports have noted that all of these symptoms can also be attributed to stress and that current research cannot separate the symptoms from placebo effects.

### **Genotoxic effects**

A large early 2009 meta-study of 101 scientific publications on genotoxicity of RF electromagnetic fields shows that 49 report a genotoxic effect and 42 do not. Research published in 2004 by a team at the University of Athens had a reduction in reproductive capacity in fruit flies exposed to 6 minutes of 900 MHz pulsed radiation for five days. Subsequent research, again conducted on fruit flies, was published in 2007, with the same exposure pattern but conducted at both 900 MHz and 1800 MHz, and had similar changes in reproductive capacity with no significant difference between the two frequencies. Following additional tests published in a third article, the authors stated they thought their research suggested the changes were "...due to degeneration of large numbers of egg chambers after DNA fragmentation of their constituent cells ...". Australian research conducted in 2009 by subjecting in vitro samples of human spermatozoa to radio-frequency radiation at 1.8 GHz and specific absorption rates (SAR) of 0.4 to 27.5 W/kg showed a correlation between increasing SAR and decreased motility and vitality in sperm, increased oxidative stress and 8-Oxo-2'-deoxyguanosine markers, stimulating DNA base adduct formation and increased DNA fragmentation.

In 1995, in the journal *Bioelectromagnetics*, Henry Lai and Narendra P. Singh reported damaged DNA after two hours of microwave radiation at levels deemed safe according to government standards. Later, in December 2004, a pan-European study named REFLEX (Risk Evaluation of Potential Environmental Hazards from Low Energy Electromagnetic Field (EMF) Exposure Using Sensitive in vitro Methods), involving 12 collaborating laboratories in several countries showed some compelling evidence of DNA damage of cells in in-vitro cultures, when exposed between 0.3 to 2 watts/kg, whole-sample average. There were indications, but not rigorous evidence of other cell changes, including damage to chromosomes, alterations in the activity of certain genes and a boosted rate of cell division. Reviews of in vitro genotoxicity studies have generally concluded that RF is not genotoxic and that studies reporting positive effects had experimental deficiencies.

### **Sleep and EEG effects**

Sleep, EEG and waking rCBF have been studied in relation to RF exposure for a decade now, and the majority of papers published to date have found some form of effect. While a Finnish study failed to find any effect on sleep or other cognitive function from pulsed RF exposure, most other papers have found significant effects on sleep. Two of these papers found the effect was only present when the exposure was pulsed (amplitude modulated), and one early paper actually found that sleep quality (measured by the amount of participants' broken sleep) actually improved.

While some papers were inconclusive or inconsistent, a number of studies have now demonstrated reversible EEG and rCBF alterations from exposure to pulsed RF exposure. German research from 2006 found that statistically significant EEG changes could be consistently found, but only in a relatively low proportion of study participants (12 - 30%).

## **Health hazards of base stations**

Another area of concern is the radiation emitted by the fixed infrastructure used in mobile telephony, such as base stations and their antennas, which provide the link to and from mobile phones. This is because, in contrast to mobile handsets, it is emitted continuously and is more powerful at close quarters. On the other hand, field intensities drop rapidly with distance away from the base of the antenna because of the attenuation of power with the square of distance. Base station emissions must comply with safety guidelines. Some countries however (such as South Africa for example) have no health regulations governing the placement of base stations.

Several surveys have found increases of symptoms depending upon proximity to electromagnetic sources such as mobile phone base stations.

A 2002 survey study by Santini *et al.* in France found a variety of self-reported symptoms for people who reported that they were living within 300 metres (984 ft) of GSM cell towers in rural areas, or within 100 m (328 ft) of base stations in urban areas. Fatigue, headache, sleep disruption and loss of memory were among the symptoms reported. Similar results have been obtained with GSM cell towers in Spain, Egypt, Poland and Austria. No major studies have been reported in which health effects did not occur on actual populations living near mobile base stations. However, there are significant challenges in conducting studies of populations near base stations, especially in assessment of individual exposure. Self-report studies can also be vulnerable to the nocebo effect.

A study conducted at the University of Essex and another in Switzerland concluded that mobile phone masts were unlikely to be causing these short term effects in a group of volunteers who complained of such symptoms. The Essex study has been criticised as being skewed due to drop-outs of test subjects, although these criticisms were answered by the authors.

As technology progresses and data demands have increased on the mobile network, towns and cities have seen the number of towers increase sharply, including 3G towers which work with larger bandwidths. Many measurements and experiments have shown that transmitter power levels are relatively low - in modern 2G antennas, in the range of 20 to 100 W, with the 3G towers causing less radiation than the already present 2G network. An average radiation power output of 3 W is used. The use of 'micro-cell geometries' (large numbers of transmitters in an area but with each individual transmitter running very low power) inside cities has decreased the amount of radiated power even further. The radiation exposure from these antennas, while generally low level, is continuous.

Experts consulted by France consider it is mandatory that main antenna axis not to be directly in front of a living place at a distance shorter than 100 meters. This recommendation was modified in 2003 to say that antennas located within a 100-metre radius of primary schools or childcare facilities should be better integrated into the cityscape and was not included in a 2005 expert report.

## **Occupational health hazards**

Telecommunication workers who spend time at a short distance from the active equipment, for the purposes of testing, maintenance, installation, etcetera, may be at risk of much greater exposure than the general population. Many times base stations are not turned off during maintenance, but the power being sent through to the antennas is cut off, so that the workers do not have to work near live antennas.

A variety of studies over the past 50 years have been done on workers exposed to high RF radiation levels; studies including radar laboratory workers, military radar workers, electrical workers, and amateur radio operators. Most of these studies found no increase in cancer rates over the general population or a control group. Many positive results could have been attributed to other work environment conditions, and many negative results of reduced cancer rates also occurred.

## **Safety standards and licensing**

In order to protect the population living around base stations and users of mobile handsets, governments and regulatory bodies adopt safety standards, which translate to limits on exposure levels below a certain value. There are many proposed national and international standards, but that of the International Commission for Non-Ionizing Radiation Protection (ICNIRP) is the most respected one, and has been adopted so far by more than 80 countries. For radio stations, ICNIRP proposes two safety levels: one for occupational exposure, another one for the general population. Currently there are efforts underway to harmonise the different standards in existence.

Radio base licensing procedures have been established in the majority of urban spaces regulated either at municipal/county, provincial/state or national level. Mobile telephone

service providers are, in many regions, required to obtain construction licenses, provide certification of antenna emission levels and assure compliance to ICNIRP standards and/or to other environmental legislation.

Many governmental bodies also require that competing telecommunication companies try to achieve sharing of towers so as to decrease environmental and cosmetic impact. This issue is an influential factor of rejection of installation of new antennas and towers in communities.

The safety standards in the U.S. are set by the Federal Communications Commission (FCC). The FCC has based its standards primarily on those standards established by the Institute of Electrical and Electronics Engineers (IEEE), specifically Subcommittee 4 of the "International Committee on Electromagnetic Safety".

Switzerland has set safety limits lower than the ICNIRP limits for certain "sensitive areas" (classrooms, for example).

## **In the Courts**

In the USA, a small number of personal injury lawsuits have been filed by individuals against cellphone manufacturers, such as Motorola, NEC, Siemens and Nokia, on the basis of allegations of causation of brain cancer and death. In US federal court, expert testimony relating to science must be first evaluated by a judge, in a Daubert hearing, to be relevant and valid before it is admissible as evidence. In one case against Motorola, the plaintiffs alleged that the use of wireless handheld telephones could cause brain cancer, and that the use of Motorola phones caused one plaintiff's cancer. The judge ruled that no sufficiently reliable and relevant scientific evidence in support of either general or specific causation was proffered by the plaintiffs; accepted a motion to exclude the testimony of the plaintiffs' experts; and denied a motion to exclude the testimony of the defendants' experts.

### **French High Court ruling against telecom company**

In February 2009 the telecom company Bouygues Telecom was ordered to take down a mobile phone mast due to uncertainty about its effect on health. Residents in the commune Charbonnières in the Rhône department had sued the company claiming adverse health effects from the radiation emitted by the 19 meter tall antenna. The milestone ruling by the Versailles Court of Appeal reversed the burden of proof which is usual in such cases by emphasizing the extreme divergence between different countries in assessing safe limits for such radiation. The court stated that, "Considering that, while the reality of the risk remains hypothetical, it becomes clear from reading the contributions and scientific publications produced in debate and the divergent legislative positions taken in various countries, that uncertainty over the harmlessness of exposure to the waves emitted by relay antennas persists and can be considered serious and reasonable".

# Precaution

## Precautionary principle

In 2000, the World Health Organization (WHO) recommended that the precautionary principle could be voluntarily adopted in this case. It follows the recommendations of the European Community for environmental risks. According to the WHO, the "precautionary principle" is "a risk management policy applied in circumstances with a high degree of scientific uncertainty, reflecting the need to take action for a potentially serious risk without awaiting the results of scientific research." Other less stringent recommended approaches are prudent avoidance principle and as low as reasonably practicable. Although all of these are problematic in application, due to the widespread use and economic importance of wireless telecommunication systems in modern civilization, there is an increased popularity of such measures in the general public, though also evidence that such approaches may increase concern. They involve recommendations such as the minimization of cellphone usage, the limitation of use by at-risk population (such as children), the adoption of cellphones and microcells with as low as reasonably practicable levels of radiation, the wider use of hands-free and earphone technologies such as Bluetooth headsets, the adoption of maximal standards of exposure, RF field intensity and distance of base stations antennas from human habitations, and so forth.

## Precautionary Measures and health advisories

Some national radiation advisory authorities, including those of Austria, France, Germany, and Sweden, have recommended measures to minimize exposure to their citizens. Examples of the recommendations are:

- Use hands-free to decrease the radiation to the head.
- Keep the mobile phone away from the body.
- Do not use telephone in a car without an external antenna.

The use of "hands-free" was not recommended by the British Consumers' Association in a statement in November 2000 as they believed that exposure was increased. However, measurements for the (then) UK Department of Trade and Industry and others for the French l'Agence française de sécurité sanitaire environnementale showed substantial reductions. In 2005 Professor Lawrie Challis and others said clipping a ferrite bead onto hands-free kits stops the radio waves travelling up the wire and into the head.

Several nations have advised moderate use of mobile phones for children.

## Mobile Phones and Driving Safety



**Mobile phone** use while driving is common, but dangerous. Because of this, some jurisdictions have made the use of a cell phone while driving illegal. Others have enacted laws to ban handheld mobile phone use, but allow use of a handsfree device. In some cases restrictions are only directed to minors or those who are newly qualified license holders.

## Increased risk

Distracted driving fatalities caused by cell phone use and texting soared in the space of three years, according to new U.S. government research. Text messaging alone caused more than 16,000 deaths in car accidents from 2001 to 2007, the researchers estimated. But auto deaths involving cell phones and texting while driving rose 28 percent in just three years, from 4,572 in 2005 to 5,870 in 2008.

The Société de l'assurance automobile du Québec (SAAQ) conducted a study in 2003. Questionnaires were sent to 175,000 drivers and analysis was done on the 36,078 who responded. The questionnaire asked about driving habits, risk exposure, collisions over the past 24 months, socio-demographic information, and cell phone use. Questionnaires were supported with data from cell phone companies and police crash records. The study found that the overall relative risk (RR) of having an accident for cell phone users when compared to non-cell phone users averaged 1.38 across all groups. When adjusted for kilometers driven per year and other crash risk exposures, RR was 1.11 for men and 1.21 for women. They also found that increased cell phone use correlated with an increase in RR. When the same data were reanalyzed using a Bayesian approach, the calculated RR of 0.78 for those making less than 1 call/day and 2.27 for those with more than 7 calls/day was similar to cohort analysis.

When the data were reanalyzed using case-crossover analysis, RR was calculated at a much higher 5.13. The authors expressed concern that misclassification of phone calls due to reporting errors of the exact time of the collisions was a major source of bias with all case-crossover analysis of this issue.

Means and standard errors (in parentheses) for the Alcohol, Base line, and Cell-Phone conditions

	Alcohol	Base line	Cell Phone
Total Accidents	0	0	3
Brake Onset Time (msec)	888 (51)	943 (58)	1022 (61)
Braking Force (% of maximum)	69.6 (3.6)	56.4 (2.5)	55.2 (2.9)
Speed (MPH)	52.8 (.08)	54.9 (.08)	53.2 (.07)
Following Distance (meters)	26.5 (1.7)	27.3 (1.3)	28.5 (1.6)
½ Recovery Time	5.4 (0.3)	5.4 (0.3)	6.2 (0.4)

### Simulation study comparisons with alcohol

A 2003 study by the University of Utah psychology department measured response time, following distance, and driving speed of a control group, subjects at the legal BAC limit of 0.08%, and subjects involved in cell phone conversations. Data from the report are listed to the right.

It should be noted that the data of this study was adjusted to reflect socially accepted results. As the study notes; "... this is the third in a series of studies that we have conducted evaluating the effects of cell phone use on driving using the car following procedure. Across these three studies, 120 participants performed in both baseline and cell phone conditions. Two of the participants in our studies were involved in an accident in baseline conditions, whereas 10 participants were involved in an accident when they were conversing on a cell phone." However zero (0) drunk drivers had accidents in any of the tests. When results of this study are taken at face value it suggests that it is actually safer to drive drunk than sober.

From the report:

- Forty adults (25 men, 15 women), recruited via advertisements in local newspapers, participated in the Institutional Review Board approved study.
- Of the 40 participants, 78% owned a cell phone, and 87% of the cell phone owners reported that they have used a cell phone while driving.
- The experiment lasted approximately 10 hr (across the three days of the study)
- A PatrolSim high-fidelity driving simulator, ... manufactured by GEISIM, was used in the study.
- The cell phone was manufactured by LG Electronics Inc. (Model TP1100). For hands-free conditions, a Plantronics M135 headset (with earpiece and boom microphone) was attached to the cell phone.
- ... the participant's task was to follow the intermittently braking pace car driving in the right-hand lane of the highway.
- Initially both the participant's car and the pace car were driving at about 62 miles/hr (mph) with a following distance of 40 m
- In the alcohol session, participants drank a mixture of orange juice and vodka (40% alcohol by volume) calculated to achieve a blood alcohol concentration of 0.08% wt/vol.
- Participants drove in the 15-min car-following scenario while legally intoxicated. Average blood alcohol concentration before driving was 0.081% wt/vol and after driving was 0.078% wt/vol.
- In the cell phone session, three counterbalanced conditions, each 15 min in duration, were included: single-task baseline driving, driving while conversing on a handheld cell phone, and driving while conversing on a hands-free cell phone.
- In both cell phone conditions, the participant and a research assistant engaged in naturalistic conversations
- We used a multivariate analysis of variance (MANOVA) followed by planned contrasts to provide an overall assessment of driver performance in each of the experimental conditions.
- We performed an initial comparison of participants driving while using a handheld cell phone versus a hands-free cell phone. Both handheld and hands-free cell phone conversations impaired driving. However, there

were no significant differences in the impairments caused by these two modes of cellular communication

- Drivers in the cell-phone condition exhibited a sluggish behavior (i.e., slower reactions) which they attempted to compensate for by increasing their following distance. Drivers in the alcohol condition exhibited a more aggressive driving style, in which they followed closer, necessitating braking with greater force.
- By contrast, when participants were intoxicated, neither accident rates, nor reaction time to vehicles braking in front of the participant, nor recovery of lost speed following braking differed significantly from baseline. Overall, drivers in the alcohol condition exhibited a more aggressive driving style.
- Most importantly, our study found that accident rates in the alcohol condition did not differ from baseline; however, the increase in hard braking and the increased frequency of TTC values below 4 s are predictive of increased accident rates over the long run
- No accidents were observed in the alcohol sessions of our study. Nevertheless, alcohol clearly increases the risk of accidents in real-world settings.
- Two of the participants in our studies were involved in an accident in baseline conditions
- One factor that may have contributed to the absence of accidents in the alcohol condition of our study is that the alcohol and driving portion of the study was conducted during the daytime (between 9:00 a.m. and noon).
- We compared the cell phone driver with the drunk driver for two reasons. First, there are now clear societal norms associated with intoxicated driving, and laws in the United States expressly prohibit driving with a blood alcohol level at or above 0.08%. Logical consistency would seem to dictate that any activity that leads to impairments in driving equal to or greater than the drunk driving standard should be avoided
- Support for this study was provided through a grant from the Federal Aviation Administration.

After controlling for driving difficulty and time on task, the study concluded that cell phone drivers exhibited greater impairment than intoxicated drivers.

### **Meta-analysis**

A 2005 review by the Hawaiian legislature entitled "Cell Phone Use and Motor Vehicle Collisions: A Review of the Studies" contains an analysis of studies on cell phone/motor vehicle accident causality.

Meta-analysis by the Canadian Automobile Association and the University of Illinois found that response time while using both hands-free and hand-held phones was approximately 0.5 standard deviations higher than normal driving (i.e., an average driver,

while talking on a cell phone, has response times of a driver in roughly the 40th percentile).

### **Arguments from increase in mobile subscription**

In the US, the number of cell phone subscribers has increased by 1,262.4% between the years 1985-2008. In approximately the same period the number of crashes has fallen by 0.9% (1995-2009) and the number of fatal crashes fallen by 6.2%. It has been argued that these statistics contradict the claims that mobile use impairs driving performance. Similarly, a 2010 study from the Highway Loss Data Institute published in February 2010 reviewed auto claims from three key states along with Washington D.C. prior to cell phone bans while driving and then after. The study found no reduction in crashes, despite a 41% to 76% reduction in the use of cell phones while driving after the ban was enacted.

These statistics, while compelling, ignore other salient factors. For example, many mobile phone subscribers will not drive or be eligible to drive, and mobile ownership may have increased while usage at the wheel has declined. It should also be remembered that correlation does not imply causation. In addition, improvements in car design during the same period almost certainly have reduced the chances of a crash proving fatal.

### **As a percentage of distraction-related accidents**

Driver inattention is estimated to be a factor in between 20 to 50 percent of all police-reported crashes. Driver distraction, a sub-category of inattention, has been estimated to be a contributing factor in 8 to 13 percent of all crashes. Of distraction-related accidents, cell phone use may range from 1.5 to 5 percent of contributing factors. However, large percentages of unknowns in each of those categories may cause inaccuracies in these estimations. A 2001 study sponsored by The American Automobile Association recorded "Unknown Driver Attention Status" for 41.5 percent of crashes, and "Unknown Distraction" in 8.6 percent of all distraction related accidents. According to NHTSA, "There is clearly inadequate reporting of crashes".

Currently, "Outside person, object, event" (commonly known as rubbernecking) is the most reported cause of distraction-related accidents, followed by "Adjusting radio/cassette/CD". "Using/dialing cell phone" is eighth.

### **Handsfree device**



### Hands-free car kit

Driving while using a handsfree cellular device is not safer than using a hand held cell phone, as concluded by case-crossover studies, epidemiological, simulation, and meta-analysis . The increased "cognitive workload" involved in holding a conversation, not the use of hands, causes the increased risk. One notable exception to that conclusion is a study by headset manufacturer Plantronics, which found 71 percent of the test subjects steered more accurately, 100 percent had faster brake reaction times, and 92 percent maintained a more consistent speed when using a headset versus handheld.

The consistency of increased crash risk between hands-free and hand held cell phone use is at odds with legislation in many locations that prohibits hand held cell phone use but allows hands-free. Nevertheless, dialing a cell phone is more distracting than talking on a

cell phone, and hands-free devices that offer voice-dialing may reduce or eliminate that increased risk.

### **Comparisons with passenger conversation**

The scientific literature is mixed on the dangers of talking on a cell phone versus those of talking with a passenger. The common conception is that passengers are able to better regulate conversation based on the perceived level of danger, therefore the risk is negligible. A study by a University of South Carolina psychology researcher featured in the journal, *Experimental Psychology*, found that planning to speak and speaking put far more demands on the brain's resources than listening. Measurement of attention levels showed that subjects were four times more distracted while preparing to speak or speaking than when they were listening. The Accident Research Unit at the University of Nottingham found that the number of utterances was usually higher for mobile calls when compared to blindfolded and non-blindfolded passengers across various driving conditions. The number of questions asked averaged slightly higher for mobile phone conversations, although results were not constant across road types and largely influenced by a large number of questions on the urban roads.

A 2004 University of Utah simulation study that compared passenger and cell-phone conversations concluded that the driver performs better when conversing with a passenger because the traffic and driving task become part of the conversation. Drivers holding conversations on cell phones were four times more likely to miss the highway exit than those with passengers, and drivers conversing with passengers showed no statistically significant difference from lone drivers in the simulator. A study led by Andrew Parkes at the Transport Research Laboratory, also with a driving simulator, concluded that hands-free phone conversations impair driving performance more than other common in-vehicle distractions such as passenger conversations.

In contrast, the University of Illinois meta-analysis concluded that passenger conversations were just as costly to driving performance as cell phone ones. AAA ranks passengers as the third most reported cause of distraction-related accidents at 11 percent, compared to 1.5 percent for cellular telephones. A simulation study funded by the American Transportation Research Board concluded that driving events that require urgent responses may be influenced by in-vehicle conversations, and that there is little practical evidence that passengers adjusted their conversations to changes in the traffic. It concluded that drivers' training should address the hazards of both mobile phone and passenger conversations.

### **Texting**



Texting while driving leads to increased distraction

**Texting while driving** is the act of composing, sending, or reading text messages, email, or making other similar use of the internet on a mobile device, while operating a motor vehicle, such as an automobile, truck or train. The practice has been viewed by many people and authorities as dangerous. It has also been ruled as the cause of some motor vehicle accidents, and in some places has been outlawed or restricted. Texting while driving leads to increased distraction behind the wheel. In 2006, Liberty Mutual Insurance Group conducted a survey with more than 900 teens from over 26 high schools nationwide. The results showed that 37% of students found texting to be "very" or "extremely" distracting. A study by the AAA discovered that 46% of teens admitted to being distracted behind the wheel due to texting.

A 2009 experiment with *Car and Driver* magazine editor Eddie Alterman that took place at a deserted air strip showed that texting while driving had a greater impact on safety than driving drunk. While legally drunk, Alterman's stopping distance from 70 mph increased by 4 feet; by contrast, reading an e-mail added 36 feet, and sending a text added 70 feet. While celebrities such as Oprah Winfrey have campaigned against texting while driving, there are reports that the message hasn't been getting through to teenagers.

In the UK in 2009 Gwent Police worked with film maker Peter Watkins-Hughes and production company Zipline Creative to create the graphic short film "Cow", as part of a

campaign to stop texting while driving. The film earned honors in the Advertising Age's weekly Creativity Top 5 videos and became an overnight worldwide internet hit after being shown on the American news program *The Today Show*.

## Research

The scientific literature on the dangers of driving while sending a text message from a mobile phone, or driving while texting, is limited. A simulation study at the Monash University Accident Research Centre provided strong evidence that retrieving and, in particular, sending text messages has a detrimental effect on a number of safety-critical driving measures. Specifically, negative effects were seen in detecting and responding correctly to road signs, detecting hazards, time spent with eyes off the road, and (only for sending text messages) lateral position. Mean speed, speed variability, lateral position when receiving text messages, and following distance showed no difference. A separate, yet unreleased simulation study at the University of Utah found a sixfold increase in distraction-related accidents when texting.

The low number of scientific studies may be indicative of a general assumption that if talking on a mobile phone increases risk, then texting also increases risk, and probably more so. 89% of U.S. adults think that text messaging while driving is "distracting, dangerous and should be outlawed." The AAA Foundation for Traffic Safety has released polling data that show that 87% of people consider texting and e-mailing while driving a "very serious" safety threat, almost equivalent to the 90% of those polled who consider drunk driving a threat. Despite the acknowledgement of the dangers of texting behind the wheel, about half of drivers 16 to 24 say they have texted while driving, compared with 22 percent of drivers 35 to 44. Texting while driving received greater attention in the late 2000s, corresponding to a rise in the number of text messages being sent. The 2008 Will Smith movie *Seven Pounds* deals with Smith's character committing suicide in order to donate his organs to help save the lives of seven people to make up for the seven people he killed in a car accident because he was receiving a text message while he was driving. Texting while driving attracted interest in the media after several highly publicized car crashes were caused by texting drivers, including a May 2009 incident involving a Boston trolley car driver who crashed while texting his girlfriend. Texting was blamed in the 2008 Chatsworth train collision which killed 25 passengers. Investigations revealed that the engineer of that train had sent 45 text messages while operating. Despite these incidents, texting was still on the rise. A July 2010 Fairleigh Dickinson University PublicMind poll found 25% of New Jersey voters admitted to sending a text while driving, which was an increase from 15% in 2008. This increase could be attributed to drivers over the age of 30 sending text messages. Over 35% of New Jersey drivers aged 30 to 45 and 17% of drivers over 45 admitted to sending a text message while driving in the last year, an increase of 5-10% from 2008. Several studies have attempted to compare the dangers of texting while driving with driving under the influence. One such study was conducted by *Car and Driver* magazine in June 2009. . The study, carried out at the Oscoda-Wurtsmith Airport in Oscoda, Michigan, used two drivers in real cars and measured reaction-times to the onset of light on the windshield. The study compared the reaction times and distances of the subjects while reading a text

message, replying to the text message, and impaired. The study showed that at 35 mph, reading a text message decreased the reaction time the most, 0.12 and 0.87 seconds. Impaired driving at the same speed resulted in an increase of 0.01 and 0.07 seconds. In terms of stopping distances these times were estimated to mean:

- Unimpaired: .54 seconds to brake
- Legally drunk: add 4 feet
- Reading e-mail: add 36 feet.
- Sending a text: add 70 feet

On Sept. 29, 2010, the insurance industry’s Highway Loss Data Institute released research purporting to show that texting-while-driving bans in four states failed to reduce crashes and may instead have contributed to an increase in road accidents. U.S. Transportation Secretary Ray LaHood called the study “completely misleading.”

### **Virginia Tech Transportation Institute Study**

On July 27, 2009, the Virginia Tech Transportation Institute released preliminary findings of their study of driver distraction in commercial vehicles. Several naturalistic driving studies, of long-haul trucks as well as lighter vehicles driving six million combined miles, used video cameras to observe the drivers and road. Researchers observed 4,452 "safety-critical" events, which includes crashes, near crashes, safety-critical events, and lane deviations. 81% of the "safety-critical" events involved some type of driver distraction. Text messaging had the greatest relative risk, with drivers of heavy vehicles or trucks being more than 23 times more likely to experience a safety-critical event when texting. The study also found that drivers typically take their eyes off the forward roadway for an average of four out of six seconds when texting, and an average of 4.6 out of the six seconds surrounding safety-critical events. The study revealed that when traveling at 55 mph, a driver texting for 6 seconds is looking at the phone for 4.6 seconds of that time and travels the distance of a football field without their eyes on the road. Some of VTTI's conclusions from this study included that "texting should be banned in moving vehicles for all drivers", and that "all cell phone use should be banned for newly licensed teen drivers". The results of the study are listed in the table below.

<b>Risk Increases of Cell Phone Tasks by Vehicle Type</b>	
<b>Cell phone task</b>	<b>Risk of crash or near event crash</b>
<b>Light Vehicle Dialing</b>	2.8 times as high as non - distracted driving
<b>Light Vehicle Talking/Listening</b>	1.3 times as high as non - distracted driving
<b>Light Vehicle Reaching for object (i.e. electronic device...)</b>	1.4 times as high as non - distracted driving

<b>Heavy Vehicles/Trucks Dialing</b>	5.9 times as high as non - distracted driving
<b>Heavy Vehicles/Trucks Talking/Listening</b>	1.0 times as high as non - distracted driving
<b>Heavy Vehicles/Trucks Use/Reach for electronic device</b>	6.7 times as high as non - distracted driving
<b>Heavy Vehicles/Trucks Text messaging</b>	23.2 times as high as non - distracted driving

## 1. VTTI

## Notable crashes

- On August 29, 2007, Danny Oates was killed by a young driver of a car, allegedly texting while driving. The defense had argued that driver Jeffrey Woods had possibly suffered a seizure during the time of the accident.
- On January 3, 2008, Heather Leigh Hurd was killed by a truck driver who allegedly was texting while driving. Her father Russell Hurd has been actively supporting a law in various U.S. states called Heather's Law that would prohibit texting while driving.
- The 2008 Chatsworth train collision, which killed 25 people, and which occurred on September 12, 2008, was blamed on the operator sending text messages while operating the train.
- In 2009, a crash on the MBTA Green Line of the Boston area was blamed on a driver who was texting. This occurred nearly a year after the Newton, Massachusetts rail accident, which occurred on May 28, 2008, and was blamed on the operator using a cell phone while operating the train.
- Beverly Hills plastic surgeon Frank Ryan's fatal crash on August 16, 2010 may have been the result of distracted driving due to texting.

## Laws by location

A number of countries ban all cell phone use while driving (talking and texting).

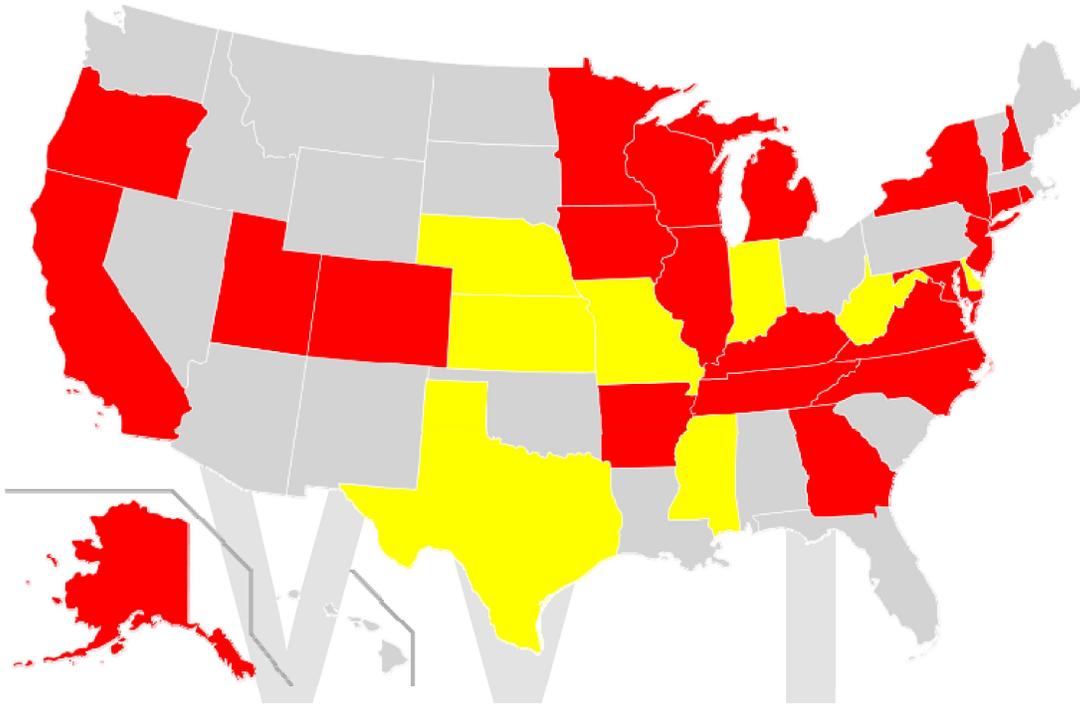
### Canada

All provinces except Alberta and New Brunswick have banned both talking on hand-held phones and texting while driving. The country's territories (Northwest Territories, Nunavut, and Yukon) have also yet to enact bans.

## United Kingdom

Any use of a mobile phone or similar device whilst driving, or supervising a learner driver, is illegal. This includes being stopped at traffic lights. The only exceptions are emergency calls to 999 or 112.

## United States



Texting while driving statutes in the United States

**Color key:** ■ Banned for all drivers ■ Banned for new drivers ■ No statute

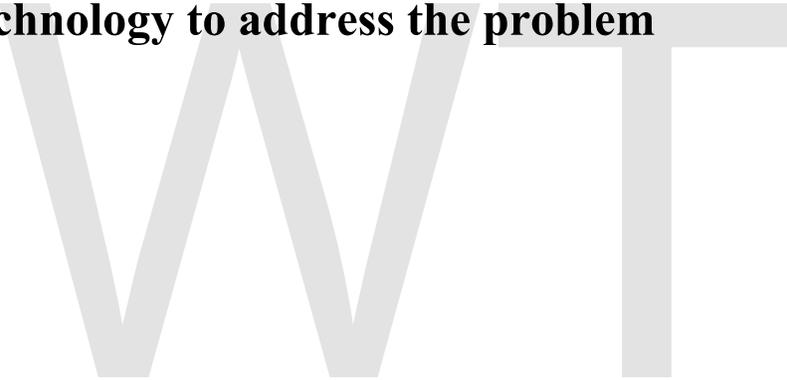
Texting while driving has been outlawed or is soon to be outlawed for all drivers in the following states: Arkansas, California, Colorado, Connecticut, Delaware, District of Columbia, Georgia, Illinois, Iowa, Louisiana, Maryland, Massachusetts, Michigan, Minnesota, New Hampshire, New Jersey, New York, North Carolina, Oregon, Tennessee, Utah, Vermont, Virginia, Washington and Wisconsin. The state of Texas prohibits school bus drivers from texting while transporting a child under 17. The states of Delaware, Indiana, Kansas, Mississippi, Missouri, Nebraska, Texas and West Virginia have laws restricting those who are underage and/or with learner's permits from texting while driving. A law enacted in 2010 by Kentucky has banned texting for all drivers, as well as cell phone usage by all drivers under 18. The latter feature is unusual in that holders of unrestricted licenses are subject to the ban; most states that have banned cell phone usage by young drivers apply their laws only to holders of restricted or graduated licenses.

In Florida, a proposed bill known as "Heather's Law" would ban all cell phone use while driving. The law was inspired by the death of Heather Hurd, who was killed in an accident allegedly caused by a truck driver who crashed into 10 cars when he was sending a text message behind the wheel.

On October 1, 2009, the U.S. Department of Transportation announced President Barack Obama's signing of an Executive Order directing federal employees not to engage in text messaging while driving government-owned vehicles, among other activities. According to Transportation Secretary Ray LaHood, "This order sends a very clear signal to the American public that distracted driving is dangerous and unacceptable. It shows that the federal government is leading by example." As a part of a larger move to combat distracted driving, the DOT and NHTSA launched the public information website [distraction.gov](http://distraction.gov).

On January 26, 2010, the US Department of Transportation announced a federal ban on texting while driving by truckers and bus drivers.

## **Using technology to address the problem**





A sign in West University Place, Texas advising drivers that they are not allowed to text

In 2009 it was reported that some companies, including iZUP, ZoomSafer, Aegis Mobility, and cellcontrol by obdEdge employ systems that place restrictions on cell phone usage based on the phone's GPS signal, data from the car itself or from nearby cellphone towers.

The use of telematics to detect drunk driving and texting while driving has been proposed. A US patent application combining this technology with a usage based insurance product was open for public comment on peer to patent. The insurance product wouldn't ban texting while driving, but would charge drivers who text and drive a higher premium.

In 2010 AdelaVoice launched, StartTalking, the world's first smartphone application that lets motorists keep their eyes on the road and hands upon the wheel. StartTalking addresses the issue of distracted driving throughout the entire process of composing, sending and receiving text messages, removing the visual and physical distractions normally associated with text messaging. StartTalking is 100% eyes-free and hands-free way to interact with the mobile phone.

## Criticism of bans

One argument against banning texting while driving is that it is safe and helpful under some circumstances. For example, a driver in a traffic jam might safely, and usefully, send a text message rescheduling his appointment. There are products like FleetSafer, MobileSafer and TeenSafer now available in Canada ([www.itiinternational.com](http://www.itiinternational.com)) that suppress the use of cell phone keyboards and screens hence no texting, emailing nor browsing. However, ZoomSafer safe driving products permit calls to be made and use of 911 using Bluetooth in-vehicle or other BT devices in a hands free manner reducing the associated risks of distracted driving. Using MobileSafer and VoiceMate also permits the sending of voice messages to other parties where the message is converted and verbally repeated upon receipt. Technology definitely contributes to safe, undistracted driving. Another argument can be made against the way the texting bans are written. Instead of banning the act of writing or reading that distracts a person from driving, such as reading a book, writing notes on a piece of paper or writing text using a keyboard of a phone, the laws mostly ban the act of sending text messages and do not say anything about how the messages were created. Using modern voice recognition technology text messages can be created eyes and hands free without ever engaging in the act of reading or writing.

The scientific literature on the dangers of driving while sending a text message from a mobile phone, or *texting while driving*, is limited. A simulation study at the Monash University Accident Research Centre has provided strong evidence that both retrieving and, in particular, sending text messages has a detrimental effect on a number of critical driving tasks. Specifically, negative effects were seen in detecting and responding correctly to road signs, detecting hazards, time spent with eyes off the road, and (only for sending text messages) lateral position. Surprisingly, mean speed, speed variability, lateral position when receiving text messages, and following distance showed no difference. A separate, yet unreleased simulation study at the University of Utah found a sixfold increase in distraction-related accidents when texting.

The low number of scientific studies may be indicative of a general assumption that if talking on a mobile phone increases risk, then texting also increases risk, and probably more so. Market research by Pinger, a company selling a voice-based alternative to texting reported that 89% of U.S. adults think that text messaging while driving is "distracting, dangerous and should be outlawed." The AAA Foundation for Traffic Safety has released polling data that show that 87% of people consider texting and e-mailing while driving a "very serious" safety threat, almost equivalent to the 90% of those polled who consider drunk driving a threat. Despite the acknowledgement of the

dangers of texting behind the wheel, about half of drivers 16 to 24 say they have texted while driving, compared with 22 percent of drivers 35 to 44.

Texting while driving received greater attention in the late 2000s, corresponding to a rise in the number of text messages being sent. Over a year approximately 2,000 teens die from texting while driving. The 2008 Will Smith movie *Seven Pounds* deals with Smith's character committing suicide in order to donate his organs to help save the lives of seven people to make up for the seven people he killed in a car accident because he was receiving a text message while he was driving. Texting while driving attracted interest in the media after several highly publicized car crashes were caused by texting drivers, including a May 2009 incident involving a Boston trolley car driver who crashed while texting his girlfriend. Texting was blamed in the 2008 Chatsworth train collision which killed 25 passengers. Investigations revealed that the engineer of that train had sent 45 text messages while operating.

On July 27, 2009, the Virginia Tech Transportation Institute released preliminary findings of their study of driver distraction in commercial vehicles. Two studies, comprising about 200 long-haul trucks driving 3 million combined miles, used video cameras to observe the drivers and road; researchers observed "4,452 safety-critical events, which includes crashes, near crashes, crash-relevant conflicts, and unintended lane deviations." 81% of the safety critical events had some type of driver distraction. Text messaging had the greatest relative risk, with drivers being 23 times more likely to experience a safety-critical event when texting. The study also found that drivers typically take their eyes off the forward roadway for an average of four out of six seconds when texting, and an average of 4.6 out of the six seconds surrounding safety-critical events.

## **Legislation**



A sign along Bellaire Boulevard in Southside Place, Texas states that using mobile phones while driving is prohibited from 7:30 AM to 9:30 AM and from 2:00 PM to 4:15 PM

Accidents involving a driver being distracted by talking on a mobile phone have begun to be prosecuted as negligence similar to driving while intoxicated. In the United Kingdom, from 27 February 2007, motorists who are caught using a hand-held mobile phone while driving will have three penalty points added to their license in addition to the fine of £60. This increase was introduced to try to stem the increase in drivers ignoring the law. Israel, Japan, Portugal and Singapore prohibit all mobile phone use while driving, including use of hands-free devices. New Zealand bans hand held cellphone use from 1 November 2009. Many states in the United States have banned texting on cell phones while driving. Illinois became the 17th American state to enforce this law. As of July

2010, 30 states had banned texting while driving, with Kentucky becoming the most recent addition on July 15.

WWT

# Wireless Electronic Devices and Health

The World Health Organization has acknowledged that electromagnetic fields (EMFs) are influencing the environment (but not people), and that some people are worried about possible effects. In response to public concern, the World Health Organization established the *International EMF Project* in 1996 to assess the scientific evidence of possible health effects of EMF in the frequency range from 0 to 300 GHz. They have stated that although extensive research has been conducted into possible health effects of exposure to many parts of the frequency spectrum, all reviews conducted so far have indicated that exposures are below the limits recommended in the ICNIRP (1998) EMF guidelines, covering the full frequency range from 0–300 GHz, and do not produce any known adverse health effect.

International guidelines on exposure levels to microwave frequency EMFs such as ICNIRP limit the power levels of wireless devices and it is uncommon for wireless devices to exceed the guidelines. These guidelines only take into account thermal effects, as nonthermal effects have not been conclusively demonstrated. The official stance of the Health Protection Agency is that “[T]here is no consistent evidence to date that WiFi and WLANs adversely affect the health of the general population.” And also that “...it is a sensible precautionary approach...to keep the situation under ongoing review...”.

## Exposure difference to mobile phones

Users of wireless devices are typically exposed for much longer periods than for mobile phones and the strength of wireless devices is not significantly less. Whereas a mobile phone can range from 21 dBm (125 mW) for Power Class 4 to 33 dBm (2W) for Power class 1, a wireless router can range from a typical 15 dBm (30 mW) strength to 27 dBm (500 mW) on the high end.

Wireless routers can be located significantly farther away from users' heads than a mobile phone, resulting in far less exposure overall. The Health Protection Agency (HPA) claims that if a person spends one year in a Wi-Fi hotspot, they will receive the same dose of radio waves as if they had made a 20-minute call on a mobile phone. Nevertheless, the same is not true of Wi-Fi enabled laptops, which are not as far away.

The HPA also acknowledges that due to the mobile phone's adaptive power ability, a DECT cordless phone's radiation could actually exceed the radiation of a mobile phone. The HPA explains that while the DECT cordless phone's radiation has an average output power of 10 mW, it is actually in the form of 100 bursts per second of 250 mW, a strength comparable to some mobile phones.

## **Wireless LAN**

Most wireless LAN equipment is designed to work within predefined standards. Wireless access points are also often close to humans, but the drop off in power over distance is fast, following the inverse-square law. However, wireless laptops are typically used close to humans. WiFi has been anecdotally linked to electromagnetic hypersensitivity, e.g., in Toronto, Canada schoolchildren as well as staff workers of France National Library.

The HPA's position is that "...radio frequency (RF) exposures from WiFi are likely to be lower than those from mobile phones." It also saw "...no reason why schools and others should not use WiFi equipment." In October 2007, the HPA launched a new "systematic" study into the effects of WiFi networks on behalf of the UK government, in order to calm fears that had appeared in the media in a recent period up to that time". Dr Michael Clark, of the HPA, says published research on mobile phones and masts does not add up to an indictment of WiFi.

## **Bluetooth**

Bluetooth also uses the microwave frequency spectrum in the range of 2.4 GHz to 2.4835 GHz. The radiated output power of Bluetooth devices varies between 1 and 100 mW, and can operate continuously or sporadically (on demand), so total exposure to EMF radiation is quite variable. Bluetooth devices have not been linked with any health issues.

## **Other devices**

Radio frequency in the microwave and radio spectrum is used in a number of practical devices for professional and home use, such as:

- DECT and other cordless phones operating at a wide range of frequencies
- Remote control devices for opening gates, etc.
- Portable two-way radio communication devices, such as walkie-talkies
- Wireless security (alarm) systems
- Wireless security video cameras
- Radio links between buildings for data communication
- Baby monitors

In addition, electrical and electronic devices of all kinds emit EM fields around their working circuits, generated by oscillating currents. Humans are in daily contact with

computers, video display monitors, TV screens, microwave ovens, fluorescent lamps, electric motors of several kinds (such as washing machines, kitchen appliances [like electric can openers, blenders, and mixers], water pumps, etc.) and many others. A study of bedroom exposure in 2009 showed the highest ELF-EF from bedside lights and the highest ELF-MF from transformer devices, while the highest RF-ELF came from DECT cordless phones and outside cellphone base stations; all exposures were well below International Commission on Non-Ionizing Radiation Protection (ICNIRP) guideline levels. The highest typical daily exposure, according to a study of 2009, came from cellphone base stations, cellphones and DECT cordless phones, with the highest exposure locations in trains, airports and buses. The typical background power of electromagnetic fields in the home can vary from zero to 5 milliwatts per meter squared. Long-time effects of these electromagnetic fields on human and animal health are still unknown, and most of the studies available have shown no effect. However, the powerful fields produced by radio (and then TV) transmitters have been present for more than 100 years now with no established effects on people's health.

The image shows the letters 'WWT' in a large, bold, sans-serif font. The letters are light gray and are centered horizontally on the page. The 'W' is composed of three vertical strokes, and the 'T' is a single vertical stroke with a horizontal top bar.

# Electromagnetic Radiation and Health

Electromagnetic radiation can be classified into ionizing radiation and non-ionizing radiation, based on whether it is capable of ionizing atoms and breaking chemical bonds. Ultraviolet and higher frequencies, such as X-rays or gamma rays are ionizing.

Non-ionizing radiation, discussed here, is associated with two major potential hazards: electrical and biological. Additionally, induced electric current caused by radiation can generate sparks and create a fire or explosive hazard.

## Types of hazards

### Electrical hazards

The oscillating electric and magnetic fields in electromagnetic radiation will induce an electric current in any conductor through which it passes. Strong radiation can induce current capable of delivering an electric shock to persons or animals. It can also overload and destroy electrical equipment. The induction of currents by oscillating magnetic fields is also the way in which solar storms disrupt the operation of electrical and electronic systems, causing damage to and even the explosion of power distribution transformers, blackouts (as in 1989), and interference with electromagnetic signals (*e.g.* radio, TV, and telephone signals).

### Fire hazards

Extremely high power electromagnetic radiation can cause electric currents strong enough to create sparks (electrical arcs) when an induced voltage exceeds the breakdown voltage of the surrounding medium (*e.g.* air). These sparks can then ignite flammable materials or gases, possibly leading to an explosion.

This can be a particular hazard in the vicinity of explosives or pyrotechnics, since an electrical overload might ignite them. This risk is commonly referred to as HERO (Hazards of Electromagnetic Radiation to Ordnance). MIL-STD-464A mandates

assessment of HERO in a system, but Navy document OD 30393 provides design principles and practices for controlling electromagnetic hazards to ordnance.

On the other hand, the risk related to fueling is known as HERF (Hazards of Electromagnetic Radiation to Fuel). NAVSEA OP 3565 Vol. 1 could be used to evaluate HERF, which states a maximum power density of 0.09 W/m<sup>2</sup> for frequencies under 225 MHz (i.e. 4.2 meters for a 40 W emitter).

## **Biological hazards**

The best understood biological effect of electromagnetic fields is to cause dielectric heating. For example, touching or standing around an antenna while a high-power transmitter is in operation can cause severe burns. These are exactly the kind of burns that would be caused inside a microwave oven.

This heating effect varies with the power and the frequency of the electromagnetic energy. A measure of the heating effect is the specific absorption rate or SAR, which has units of watts per kilogram (W/kg). The IEEE and many national governments have established safety limits for exposure to various frequencies of electromagnetic energy based on SAR, mainly based on ICNIRP Guidelines, which guard against thermal damage.

There are publications which support the existence of complex biological effects of weaker *non-thermal* electromagnetic fields, including weak ELF magnetic fields and modulated RF and microwave fields. Fundamental mechanisms of the interaction between biological material and electromagnetic fields at non-thermal levels are not fully understood.

**DNA fragmentation.** A 2009 study at the University of Basel in Switzerland found that intermittent (but not continuous) exposure of human cells to a 50 Hz electromagnetic field at a flux density of 1 mT (or 10 G) induced a slight but significant increase of DNA fragmentation in the Comet assay. However that level of exposure is already above current established safety exposure limits.

## **Positions of governments and scientific bodies**

### **World Health Organization**

"The Task Group concluded that there are no substantive health issues related to ELF *electric* fields at levels generally encountered by members of the public.... [O]n balance, the evidence [about *magnetic* fields being] related to childhood leukaemia is not strong enough to be considered causal.... A number of other adverse health effects have been studied for possible association with ELF magnetic field exposure. These include other childhood cancers, cancers in adults, depression, suicide, cardiovascular disorders, reproductive dysfunction, developmental disorders, immunological modifications, neurobehavioural effects and neurodegenerative disease. The WHO Task Group

concluded that scientific evidence supporting an association between ELF magnetic field exposure and all of these health effects is much weaker than for childhood leukaemia. In some instances (i.e. for cardiovascular disease or breast cancer) the evidence suggests that these fields do not cause them."

### **Health Canada**

"There is no *conclusive evidence* of any harm caused by exposures [to electric and magnetic fields] at levels found in Canadian homes and schools, including those located just outside the boundaries of power line corridors."

### **U.S. military definition**

In Federal Standard 1037C, the United States government adopts the following definition:

**Electromagnetic radiation hazards (RADHAZ or EMR hazards):** Hazards caused by a transmitter/antenna installation that generates electromagnetic radiation in the vicinity of ordnance, personnel, or fueling operations in excess of established safe levels or increases the existing levels to a hazardous level; or a personnel, fueling, or ordnance installation located in an area that is illuminated by electromagnetic radiation at a level that is hazardous to the planned operations or occupancy. These hazards will exist when an electromagnetic field of sufficient intensity is generated to: (a) induce or otherwise couple currents and/or voltages of magnitudes large enough to initiate electroexplosive devices or other sensitive explosive components of weapon systems, ordnance, or explosive devices; (b) cause harmful or injurious effects to humans and wildlife; (c) create sparks having sufficient magnitude to ignite flammable mixtures of materials that must be handled in the affected area. —Department of Defense Dictionary of Military and Associated Terms

## **Electric power transmission**

The preponderance of evidence suggests that the low-power, low-frequency, electromagnetic radiation associated with household current does not constitute a short or long term health hazard, and whilst some biophysical mechanisms for the promotion of cancer have been proposed (such as the electric fields around power lines attracting aerosol pollutants), none have been substantiated. Nevertheless, some research has implicated exposure in a number of adverse health effects. These include, but are not limited to, childhood leukemia, adult leukemia, neurodegenerative diseases (such as amyotrophic lateral sclerosis), miscarriage, and clinical depression.

### **Mitigation**

One response to the potential dangers of overhead power lines is to place them underground. The earth and enclosures surrounding underground cables prevent the electric field from radiating significantly beyond the power lines, and greatly reduce the magnetic field strength radiating from the power lines, into the surrounding area. However, the cost of burying and maintaining cables at transmission voltages is several times greater than overhead power lines.

## **Leukemia and cancer**

### **Suggesting no significant link**

In 1997 the National Cancer Institute (NCI) released a report published in the New England Journal of Medicine, the result of a seven-year epidemiological investigation. The study investigated 638 children with acute lymphoblastic leukemia (ALL) and 620 controls and concluded that their study provided "little evidence that living in homes characterized by high measured time-weighted average magnetic-field levels or by the highest wire-code category increases the risk of ALL in children." Following the report, the US Department of Energy disbanded the EMF Research and Public Information Dissemination (RAPID) Program, saying that its services were no longer needed.

In 2005 the Canadian government said, "The outcome of a recently conducted pooled analysis of several epidemiological studies shows a two-fold increase in the risk of leukemia in children living in homes, where the average magnetic field levels are greater than 0.4 microtesla (4 milligauss). [However,] it is the opinion of [this committee] that the epidemiological evidence to date is not strong enough to justify a conclusion that EMFs in Canadian homes, regardless of locations from power lines, cause leukemia in children."

The World Health Organization issued a fact sheet, No. 322, in June, 2007 based on the findings of a WHO work group (2007), the IARC (2002) and the ICNIRP (2003), which reviewed research conducted since the earlier publication. The fact sheet says "that there are no substantive health issues related to ELF electric fields at levels generally encountered by members of the public." For ELF magnetic fields, the fact sheet says, "the evidence related to childhood leukaemia is not strong enough to be considered causal", and "[as regards] other childhood cancers, cancers in adults, ... The WHO Task Group concluded that scientific evidence supporting an association between ELF magnetic field exposure and all of these health effects is much weaker than for childhood leukaemia. In some instances (i.e., for ... breast cancer) the evidence suggests that these fields do not cause them."

According to Dr. Lakshmikumar at the National Physical Laboratory, India, a direct, causal, link between RF radiation and cancer (including leukemia) would require one to be "willing to discard Planck's Law... and the entire body of quantum physics."

In 2010, Maslanyj *et al.*, applying the Bradford-Hill criteria to available evidence, considered the application of low-cost exposure reduction measures as appropriate

precautionary responses to "small and uncertain public health risks". Even after pooling all the data, they found it fell short of establishing "strength of association, dose-response relationship, biological plausibility and coherence, and analogy". They recognised that controversy would continue so long as other interpretations of the data were possible.

### **Suggesting a significant link**

In 2001, Ahlbom *et al.* conducted a review into EMFs and Health, and found that there was a doubling in childhood leukemia for magnetic fields of over 0.4  $\mu\text{T}$ , but said that "This is difficult to interpret in the absence of a known mechanism or reproducible experimental support".

In 2002 a study by Michelozzi *et al.* found a relationship between leukemia and proximity to the Vatican Radio station transmitters.

In 2005 Draper *et al.* found a 70% increase in childhood leukemia for those living within 200 metres (656 ft) of an overhead transmission line, and a 23% increase for those living between 200 and 600 metres (656 and 1,969 ft). Both of these results were statistically significant. The authors considered it unlikely that the increase from 200 m to 600 m is related to magnetic fields as they are well below 0.4  $\mu\text{T}$  at this distance. Bristol University (UK) has published work on a theory that could account for this increase, and would also provide a potential mechanism, being that the electric fields around power lines attract aerosol pollutants.

### **Other findings**

The World Health Organisation issued Factsheet No. 263 in October 2001 on ELF (Extremely low frequency) EMFs and cancer. It said that they were "possibly carcinogenic", based primarily on IARC's similar evaluation with respect to childhood leukemia. It also said that there was "insufficient" data to draw any conclusions on other cancers.

In 2007, the UK Health Protection Agency produced a paper showing that 43% of homes with magnetic fields of over 0.4  $\mu\text{T}$  are associated with overground or underground circuits of 132 kV and above.

A study in Sweden has shown a doubling of PCB concentrations on pine needles directly beneath a 400 kV power line, compared with reference sites further away from the power line. This implies that corona ions and/or EMF could possibly interact with semi-volatile organic pollutants, and cause an increased deposition.

### **UK SAGE report**

The UK Department of Health set up the Stakeholder Advisory Group on ELF EMFs (SAGE) to explore the implications and to make recommendations for a precautionary approach to power frequency electric and magnetic fields in light of any evidence of a

link between EMF and childhood leukemia. The first interim assessment of this group was released in April 2007 , and found that the link between proximity to power lines and childhood leukemia was sufficient to warrant a precautionary recommendation, including an option to lay new power lines underground where possible and to prevent the building of new residential buildings within 60 m (197 ft) of existing power lines. The latter of these options was not an official recommendation to government as the cost-benefit analysis based on the increased risk for childhood leukemia alone was considered insufficient to warrant it. The option was considered necessary for inclusion as, if found to be real, the weaker association with other health effects would make it worth implementing.

## **Mobile telephones**

**Mobile phone radiation and health** concerns have been raised, especially following the enormous increase in the use of wireless mobile telephony throughout the world (as of August 2005, there were more than 2 billion users worldwide). Mobile phones use electromagnetic radiation in the microwave range, and some believe this may be harmful to human health. These concerns have induced a large body of research (both epidemiological and experimental, in non-human animals as well as in humans). Concerns about effects on health have also been raised regarding other digital wireless systems, such as data communication networks.

The World Health Organization, based upon the consensus view of the scientific and medical communities, states that health effects (*e.g.* headaches or promotion of cancer) are unlikely to be caused by cellular phones or their base stations, and expects to make recommendations about mobile phones in the third quarter of 2010 at the earliest, or the first quarter of 2011 at the latest.

# Electromagnetic Hypersensitivity

**Electromagnetic hypersensitivity (EHS)**, also referred to as **electrohypersensitivity** and **electrical sensitivity (ES)**, is a set of claims of adverse medical symptoms purportedly caused by exposure to electromagnetic fields. Although effects of electromagnetic fields on the body are established, self-described sufferers of electromagnetic hypersensitivity report responding to non-ionizing electromagnetic fields (or electromagnetic radiation) at intensities well below the limits permitted by international radiation safety standards. The majority of provocation trials to date have found that self-described sufferers of electromagnetic hypersensitivity are unable to distinguish between exposure to real and sham electromagnetic fields, and it is not recognized as a medical condition by the medical or scientific communities.

## Symptoms and severity

Initial reports of electromagnetic hypersensitivity in the medical literature focused on individuals who reported symptoms following work with computer monitors. Many other electrical devices have been claimed to cause symptoms, and recent surveys of electromagnetic hypersensitivity sufferers have found that base stations for mobile and cordless phones, overhead power lines, electrical transformers, and mobile phone handsets are now the most commonly cited sources of ill health related to electromagnetism.

Self-described electromagnetic hypersensitivity sufferers tend to report non-specific symptoms: that is, the symptoms can occur with many different illnesses or diseases. Initial Swedish and Nordic reports were mainly of facial skin effects attributed to extensive use of visual display units, such as dry eyes and burning skin.

Recently a smaller group of people in Europe as a whole and in the USA have reported general and severe symptoms such as headache, fatigue, tinnitus, dizziness, memory deficits, irregular heart beat, and whole-body skin symptoms. A 2005 Health Protection Agency report noted the overlap in many sufferers with other syndromes known as

symptom-based conditions, FSS (Functional Somatic Syndromes) and IEI (Idiopathic Environmental Intolerance). Levitt proposed ties between electromagnetic fields and some of these 20th century maladies, including Chronic Fatigue Syndrome, Gulf War Syndrome, and Autism.

Figures from Carlsson *et al.* show that over 50% of people reporting electromagnetic hypersensitivity in their study also reported multiple chemical sensitivity or similar conditions. Other authors have noted that people reporting severe electromagnetic hypersensitivity generally have these conditions or have had high levels of use of electrical equipment such as mobile phones.

Those reporting electromagnetic hypersensitivity will usually describe different levels of susceptibility to electric fields, magnetic fields and various frequencies of electromagnetic waves (including fluorescent and low-energy lights, and microwaves from mobile and cordless/portable phones), with no consistency in the severity of symptoms between sufferers. Other surveys of electromagnetic hypersensitivity sufferers have not been able to find any consistent pattern to these symptoms. Instead symptoms reflecting almost every part of the body have been attributed to electromagnetic field exposure.

A minority of people who report electromagnetic hypersensitivity claim to be severely affected by it. For instance, one survey has estimated that approximately 10% of electromagnetic hypersensitivity sufferers in Sweden were on sick leave or have taken early retirement or a disability pension, compared to 5% of the general population, while a second survey has reported that of 3046 people who experienced 'annoyance' from electrical equipment, 340 (11%) reported 'much' annoyance. For those who report being severely affected, their symptoms can have a significant impact on their quality of life; with sufferers reporting physical, mental and social impairment and psychological distress.

## Prevalence

The prevalence of claimed electromagnetic hypersensitivity has been estimated as being between a few cases per million to 5% of the population depending on the location and definition of the condition.

In 2002, a questionnaire survey of 2,072 people in California found that the prevalence of self-reported electromagnetic hypersensitivity within the sample group was 3% (95% CI 2.8–3.68%), with electromagnetic hypersensitivity being defined as "being allergic or very sensitive to getting near electrical appliances, computers, or power lines" (response rate 58.3%).

A similar questionnaire survey from the same year in Stockholm County (Sweden), found a 1.5% prevalence of self-reported electromagnetic hypersensitivity within the sample group, with electromagnetic hypersensitivity being defined as "hypersensitivity or allergy to electric or magnetic fields" (response rate 73%).

A 2004 survey in Switzerland found a 5% prevalence of claimed electromagnetic hypersensitivity in the sample group of 2,048.

In 2007, a UK survey aimed at a randomly selected group of 20,000 people found a prevalence of 4% for symptoms self-attributed to electromagnetic exposure.

A group of scientists also attempted to estimate the number of people reporting "subjective symptoms" from electromagnetic fields for the European Commission. In the words of a HPA review, they concluded that "the differences in prevalence were at least partly due to the differences in available information and media attention around electromagnetic hypersensitivity that exist in different countries. Similar views have been expressed by other commentators."

There are currently over thirty support groups across the world for people reporting electromagnetic hypersensitivity.

## **Scientific evidence and Etiology**

Although individuals who report electromagnetic hypersensitivity believe that electromagnetic fields from common electrical devices trigger or exacerbate their symptoms, it has not been established that these fields play any role in the etiology of sensitivity symptoms. Exposures are to intensity levels below those generally accepted to cause physiological effects, and the diverse physiological effects reported are not what would be expected from high intensity electromagnetic fields. Sufferers and their support groups are convinced of a causal relationship with electromagnetic fields, but presently the scientific literature does not support such a link. Some professionals consider electromagnetic hypersensitivity to be a physical condition with an unclear cause, while others suggest that some aspects may be psychological. Reviews have suggested that psychological mechanisms may play a role in causing or exacerbating EHS symptoms. Research has also shown neurophysiological differences between sensitive individuals and controls. This may reflect either a psychophysiological stress response to participating in the study or a more general imbalance in autonomic nervous system regulation.

Some sufferers and support groups argue that studies may be influenced by the possible political implications of negative health effects from electromagnetic fields.

In 2005, a systematic review looked at the results of 31 experiments testing the role of electromagnetic fields in causing ES. Each of these experiments exposed people who reported electromagnetic hypersensitivity to genuine and sham electromagnetic fields under single- or double-blind conditions. The review concluded that:

"The symptoms described by 'electromagnetic hypersensitivity' sufferers can be severe and are sometimes disabling. However, it has proved difficult to show under blind conditions that exposure to electromagnetic fields can trigger these symptoms. This

suggests that 'electromagnetic hypersensitivity' is unrelated to the presence of electromagnetic fields, although more research into this phenomenon is required."

Seven studies were found which did report an association, while 24 could not find any association with electromagnetic fields. However, of the seven positive studies, two could not be replicated even by the original authors, three had serious methodological shortcomings, and the final two presented contradictory results. Since then, several more double-blind experiments have been published, each of which has suggested that people who report electromagnetic hypersensitivity are unable to detect the presence of electromagnetic fields and are as likely to report ill health following a sham exposure, as they are following exposure to genuine electromagnetic fields.

One of the studies which Rubin et al. reviewed, known as the Essex study, received some criticism for its methodology and analysis, and the authors responded in full to these initial criticisms. The authors noted that their study says nothing about the long-term effects of exposure to electromagnetic fields, but those affected generally claimed to respond to the fields within a few minutes.

In January, 2010 Rubin et al. published a follow up to their original review which included 15 experiments done since the last original review, bringing the totals up to 46 double-blind experiments and 1175 individuals with claimed hypersensitivity. The study confirmed the results of the original, claiming "no robust evidence could be found" to support the hypothesis that electromagnetic exposure causes EHS. The review also found that the studies included did support the role of the placebo effect in triggering acute symptoms in those with EHS.

In 2008, another systematic review reached the same conclusion as Rubin et al.

A 2005 report by the UK Health Protection Agency concluded that electromagnetic hypersensitivity needs to be considered in ways other than its etiology; that is, the suffering is real, even if the underlying cause is not thought to be related to electromagnetic fields. They also wrote that considering only whether electromagnetic radiation was a causative factor was not meeting the needs of sufferers, although continued research on etiology was essential.

In 2002, some controversy over the causal relationship was demonstrated by the Freiburger Appeal, a petition originated by the German environmental medical lobby group IGUMED, which stated that "we can see a clear temporal and spatial correlation between the appearance of [certain] disease and exposure to pulsed high-frequency microwave radiation", and demanding radical restrictions on mobile phone use. To address some of these concerns, and others, Hocking advised in a 2006 WHO proceedings that the test type and duration should be tailored to the individual, and that washout times are needed to prevent a carry-over effect of previous exposure. However, in 2005 the World Health Organization concluded that there is no known scientific basis for the belief that electromagnetic hypersensitivity is caused by exposure to electromagnetic fields.

## **Diagnosis**

Electromagnetic hypersensitivity is not currently an accepted diagnosis. In Sweden electromagnetic hypersensitivity is an officially recognized functional impairment, but it is not regarded as a disease. The Swedish Science and Popular Enlightenment Association, Vetenskap och Folkbildning (VoF), has criticized this research. At present there are no accepted research criteria other than 'self-reported symptoms', and for clinicians there is no case definition or clinical practice guideline. There is no specific test that can identify sufferers, as symptoms other than skin disorders tend to be subjective or non-specific. It is important firstly to exclude all other possible causes of the symptoms. Researchers and the WHO have stressed the need for a careful investigation. For some, complaints of electromagnetic hypersensitivity may mask organic or psychiatric illness and requires both a thorough medical evaluation to identify and treat any specific conditions that may be responsible for the symptoms, and a psychological evaluation to identify alternative psychiatric/psychological conditions that may be responsible or contribute to the symptoms.

A WHO factsheet also recommends an assessment of the workplace and home for factors that might contribute to the presented symptoms. These could include indoor air pollution, excessive noise, poor lighting (flickering light) or ergonomic factors. They also point out that "[s]ome studies suggest that certain physiological responses of [electromagnetic hypersensitivity] individuals tend to be outside the normal range. In particular, hyper reactivity in the central nervous system and imbalance in the autonomic nervous system need to be followed up in clinical investigations and the results for the individuals taken as input for possible treatment."

## **Possible treatment and symptom alleviation**

For individuals reporting electromagnetic hypersensitivity with long lasting symptoms and severe handicaps, treatment therapy should be directed principally at reducing symptoms and functional handicaps. This should be done in close co-operation with a qualified medical specialist to address the symptoms and a hygienist (to identify and, if necessary, control factors in the environment that have adverse health effects of relevance to the patient).

Those that feel that they are sensitive to electromagnetic fields generally try to reduce their exposure to electromagnetic sources as much as is practical. Complete avoidance of electromagnetic fields presents major practical difficulties in modern society. Methods often employed by sufferers include: avoiding sources of exposure; disconnecting or removing electrical devices; shielding or screening of self or residence; medication; and complementary and alternative therapy.

The UK Health Protection Agency reviewed treatments for electromagnetic hypersensitivity, and success was reported with "neutralizing chemical dilution,

antioxidant treatment, Cognitive Behavioural Therapy, Acupuncture and Shiatsu". It was noted that:

The studies reviewed suffer from a combination of the small numbers of subjects included and the potential variation both within and between study populations. Little information is given as to the attributed exposures of the subjects. These factors limit their general applicability outside the immediate study group. For those studies where detail was available, only two were placebo controlled [Acupuncture and nutrition intervention].

It was also noted in the review that success may have more to do with offering a caring environment as opposed to a specific treatment.

A 2006 systematic review identified nine clinical trials testing different treatments for ES: four studies tested cognitive behavioural therapy, two tested visual display unit filters, one tested a device emitting 'shielding' electromagnetic fields, one tested acupuncture, and one tested daily intake of tablets containing vitamin C, vitamin E, and selenium. The authors of the review concluded that:

"The evidence base concerning treatment options for electromagnetic hypersensitivity is limited and more research is needed before any definitive clinical recommendations can be made. However, the best evidence currently available suggests that cognitive behavioural therapy is effective for patients who report being hypersensitive to weak electromagnetic fields."

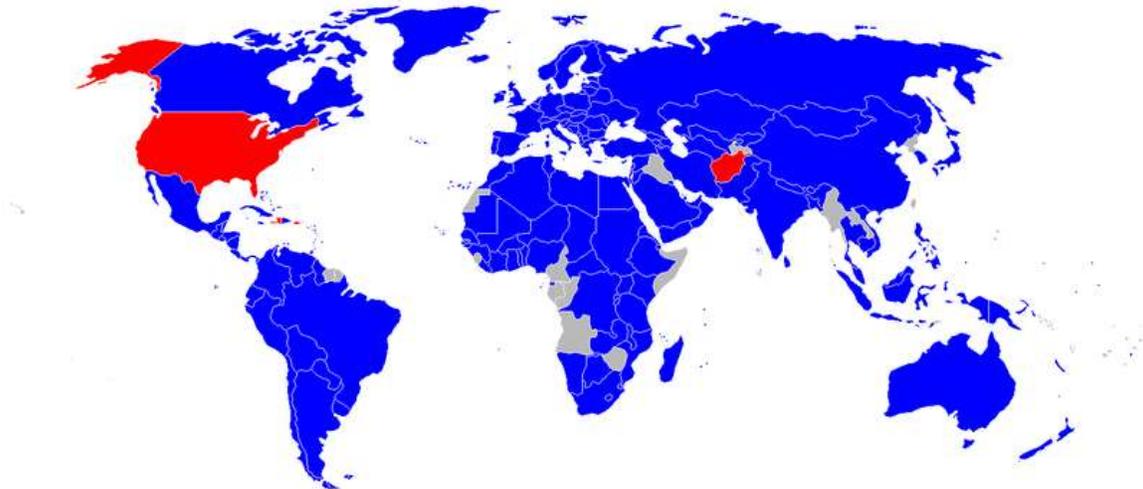
## Electronic Waste by Country



Electronic waste is often exported to developing countries.

**Electronic waste** is becoming an increasing part of the waste stream and efforts are being made to recycle and reduce this waste.

## Basel Convention



Nations that have signed and ratified, along with nations that have signed but have not ratified the agreement.

The **Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal**, usually known simply as the **Basel Convention**, is an international treaty that was designed to reduce the movements of hazardous waste between nations, and specifically to prevent transfer of hazardous waste from developed to less developed countries (LDCs). It does not, however, address the movement of radioactive waste. The Convention is also intended to minimize the amount and toxicity of wastes generated, to ensure their environmentally sound management as closely as possible to the source of generation, and to assist LDCs in environmentally sound management of the hazardous and other wastes they generate.

The Convention was opened for signature on 22 March 1989, and entered into force on 5 May 1992. A list of parties to the Convention, and their ratification status, can be found on the Basel Secretariat's web page. Of the 175 parties to the Convention, only Afghanistan, Haiti, and the United States have signed the Convention but not yet ratified it.

## History

With the tightening of environmental laws (e.g., RCRA) in developed nations in the 1970s, disposal costs for hazardous waste rose dramatically. At the same time, globalization of shipping made transboundary movement of waste more accessible, and many LDCs were desperate for foreign currency. Consequently, the trade in hazardous waste, particularly to LDCs, grew rapidly.

One of the incidents which led to the creation of the Basel Convention was the *Khian Sea* waste disposal incident, in which a ship carrying incinerator ash from the city of Philadelphia in the United States after having dumped half of its load on a beach in Haiti,

was forced away where it sailed for many months, changing its name several times. Unable to unload the cargo in any port, the crew was believed to have dumped much of it at sea.

Another is the 1988 Koko case in which 5 ships transported 8,000 barrels of hazardous waste from Italy to the small town of Koko in Nigeria in exchange for \$100 monthly rent which was paid to a Nigerian for the use of his farmland.

These practices have been deemed "Toxic Colonialism" by many developing countries.

At its most recent meeting, November 27–December 1, 2006, the Conference of the Parties of the Basel Agreement focused on issues of electronic waste and the dismantling of ships.

According to Maureen Walsh in "The global trade in hazardous wastes: domestic and international attempts to cope with a growing crisis in waste management" 42 Cath. U. Law Review 103 (1992), only around 4% of hazardous wastes that come from OECD countries are actually shipped across international borders. These wastes include, among others, chemical waste, radioactive waste, municipal solid waste, asbestos, incinerator ash, and old tires. Of internationally shipped waste that comes from developed countries, more than half is shipped for recovery and the remainder for final disposal.

Increased trade in recyclable materials has led to an increase in a market for used products such as computers. This market is valued in billions of dollars. At issue is the distinction when used computers stop being a "commodity" and become a "waste".

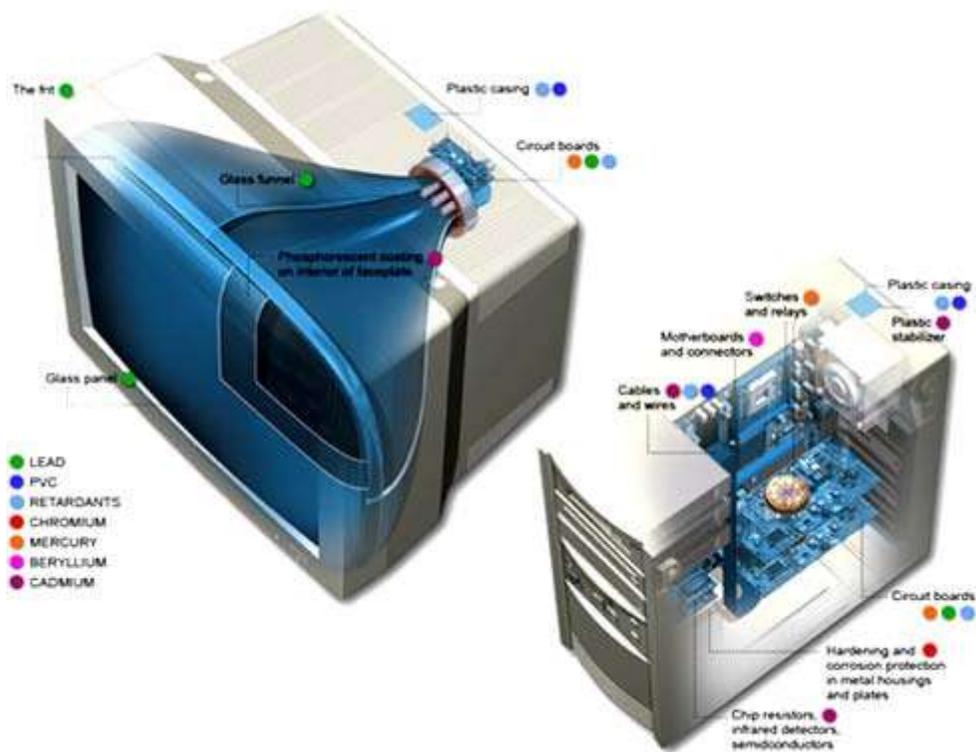
## **Definition of *hazardous waste***



4.5-Volt, D, C, AA, AAA, 9-Volt, SR41/AG3, SR44/AG13 cells are all recyclable in most countries.



Several sizes of button and coin cell. 2 9v batteries were added as a size comparison. Enlarge to see the button and coin cells' size code markings. They are all recyclable in both the UK and Ireland amongst others.



Recyclable electronic materials.

A waste will fall under the scope of the Convention if it is within the category of wastes listed in Annex I of the Convention and it does exhibit one of the hazardous characteristics contained in Annex III . In other words it must both be listed and contain a characteristic such as being explosive, flammable, toxic, or corrosive. The other way

that a waste may fall under the scope of the Convention is if it is defined as or considered to be a hazardous waste under the laws of either the exporting country, the importing country, or and of the countries of transit.

The definition of the term disposal is made in Article 2 al 4 and just refers to annex IV, which gives a list of operations which are understood as disposal or recovery. The examples of disposal are broad and include also recovery, recycling and reuse.

Annex II lists other wastes such as household wastes and residue that comes from incinerating household waste.

Radioactive waste that is covered under other international control systems and wastes from the normal operation of ships is not covered.

Annex IX attempts to define "commodities" which are not considered wastes and which would be excluded.

## **Obligations**

In addition to conditions on the import and export of the above wastes, there are stringent requirements for notice, consent and tracking for movement of wastes across national boundaries. It is of note that the Convention places a general prohibition on the exportation or importation of wastes between Parties and non-Parties. The exception to this rule is where the waste is subject to another treaty that does not take away from the Basel Convention. The United States is a notable non-Party to the Convention and has a number of such agreements for allowing the shipping of hazardous wastes to Basel Party countries.

The OECD Council also has its own control system that governs the trans-boundary movement of hazardous materials between OECD member countries. This allows, among other things, the OECD countries to continue trading in wastes with countries like the United States that have not ratified the Basel Convention.

Parties to the Convention must honor import bans of other Parties.

Article 4 of the Basel Convention calls for an overall reduction of waste generation. By encouraging countries to keep wastes within their boundaries and as close as possible to its source of generation, the internal pressures should provide incentives for waste reduction and pollution prevention.

The Convention states that illegal hazardous waste traffic is criminal but contains no enforcement provisions.

According to Article 12, Parties are directed to adopt a protocol that establishes liability rules and procedures that are appropriate for damage that comes from the movement of hazardous waste across borders.

## Basel Ban Amendment

After the initial adoption of the Convention, some LDCs and environmental organizations argued that it did not go far enough. Many nations and NGOs argued for a total ban on shipment of all hazardous waste to LDCs. In particular, the original Convention did not prohibit waste exports to any location except Antarctica but merely required a notification and consent system known as "prior informed consent" or PIC. Further, many waste traders sought to exploit the good name of recycling and begin to justify all exports as moving to recycling destinations. Many believed a full ban was needed including exports for recycling. These concerns led to several regional waste trade bans, including the Bamako Convention.

Lobbying at the 1995 Basel conference by LDCs, Greenpeace and key European countries such as Denmark, led to a decision to adopt the Basel Ban Amendment to the Basel Convention. Not yet in force, but considered morally binding by signatories, the Amendment prohibits the export of hazardous waste from a list of developed (mostly OECD) countries to developing countries. The Basel Ban applies to export for any reason, including recycling. An area of special concern for advocates of the Amendment was the sale of ships for salvage, shipbreaking. The Ban Amendment was strenuously opposed by a number of industry groups as well as nations including Australia and Canada. The number of ratification for the entry-into force of the Ban Amendment is under debate: Amendments to the convention enter into force after ratification of "three-fourths of the Parties who accepted them" [Art. 17.5]; so far, the Parties of the Basel Convention could not yet agree whether this would be three fourth of the Parties that were Party to the Basel Convention when the Ban was adopted, or three fourth of the current Parties of the Convention. The status of the amendment ratifications can be found on the Basel Secretariat's web page. The European Union fully implemented the Basel Ban in its Waste Shipment Regulation (EWSR), making it legally binding in all EU member states. Norway and Switzerland have similarly fully implemented the Basel Ban in their legislation.

In the light of the blockage concerning the entry into force of the Ban amendment, Switzerland and Indonesia have launched a "Country-led Initiative" (CLI) to discuss in an informal manner a way forward to ensure that the transboundary movements of hazardous wastes, especially to developing countries and countries with economies in transition, do not lead to an unsound management of hazardous wastes. This discussion aims at identifying and finding solutions to the reasons why hazardous wastes are still brought to countries that are not able to treat them in a safe manner. It is hoped that the CLI will contribute to the realization of the objectives of the Ban Amendment. The Basel Convention's website informs about the progress of this initiative

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Of the 172 parties to the Convention, Afghanistan, Haiti, and the United States have signed the Convention but have not yet ratified it

## **Government regulation**

The United Nations Conference on Trade and Development (UNCTAD) tends to support the repair and recycling trade. Mining to produce the same metals, to meet demand for finished products in the west, also occurs in the same countries, and UNCTAD has recommended that restrictions against recycling exports be balanced against the environmental costs of recovering those materials from mining. Hard rock mining produces 45% of all toxins produced by all industries in the United States.

Greenpeace contends that residue problems are so significant that the exports of all used electronics should be banned.

### **Asia**

Many Asian countries have legislated, or will do so, for electronic waste recycling.

South Korea, Japan and Taiwan ensure manufacturer responsibility by demanding that they recycle 75% of their annual production.

### **China**

Electronic waste in China has gained world-wide attention as a serious environmental issue.

### **Guiyu**

**Guiyu**, China, in Guangdong Province is made up of four small villages. It is the location of the largest **electronic waste** (e-waste) site on earth, . China is believed to be the predominant recipient of the world's electronic waste, with a roughly estimated one million tons of electronic waste being shipped there per year, mostly from the United States, Canada, Japan, and South Korea. It arrives via container ships through the ports of Hong Kong or Pearl River Delta at Nanhai. From there it is trucked to informal e-waste processing centers such as Guiyu, which receives more e-waste than any other area in China. Guiyu began receiving e-waste around 1995, and today, there are an estimated 150,000 e-waste workers in Guiyu who labor to process the over 100 truckloads that are dumped into the 52 square kilometer area every day. Guiyu is appropriately nicknamed the "electronic graveyard"

### **Health impacts**

Many of the primitive recycling operations in Guiyu are toxic and dangerous to workers' health. 88% of workers suffer from neurological, respiratory or digestive abnormalities or

skin diseases. Higher than average rates of miscarriage are also reported in the region. Workers use their bare hands to crack open electronics to strip away any parts that can be reused- including chips, or valuable metals such as gold, silver, etc. Workers also cook circuit boards to remove chips and solders, burn wires and other plastics to liberate metals such as copper, use highly corrosive and dangerous acid baths along the riverbanks to extract gold from the microchips, and sweep printer toner out of cartridges. Children are exposed to the dioxin-laden ash as the smoke billows around Guiyu, and finally settles on the area. The soil has been saturated with lead, chromium, tin, and other heavy metals. Discarded electronics lie in pools of toxins that leach into the groundwater, making it so polluted that the water is undrinkable. To remedy this, water must be trucked in from elsewhere. Lead levels in the river sediment are double European safety levels, according to the Basel Action Network. Lead in the blood of Guiyu's children is 88% higher than in the average child. Piles of ash and plastic waste sit on the ground beside rice paddies and dikes holding in the Lianjiang river. Guiyu is world's second most polluted spot, while Lake Karachay is world's first most polluted spot. "It was nightmarish: the air was so polluted that it was difficult for me to breathe at work." says Xu, who works to strip keyboards. "I was worried that my son might fall ill someday because of the pollution". Even visitors to the city claim to still experience headaches and strange metallic tastes in the mouth.

A recent study of the area evaluated the extent of heavy metal contamination from the site. Using dust samples, scientists analysed mean heavy metal concentrations in a Guiyu workshop and found that lead and copper were 371 and 115 times higher, respectively, than areas located 30 kilometres away. The same study revealed that sediment from the nearby Lianjiang River was found to be contaminated by polychlorinated biphenyls at a level three times greater than the guideline amount. Studies are under way to assess the extent to which chemicals like these magnify through bioaccumulation.

## **Environmental injustice/ Why Guiyu?**

American businessman Mark Dallura of Chase Electronics says: "I could care less where they (the electronics) go. My job is to make money" In the interest of business, e-waste follows the path of lowest costs and lowest standards. Because of this, the United States' priorities of gaining economic profit and protecting its citizens and environment come at a cost of the health and environment of Guiyu, among other popular export sites like Lagos, Nigeria. The economic incentives created by strict domestic regulation, non-existent regulations in developing countries, and the ease of free trade brought about by globalization, force recyclers to export e-waste. It is estimated that shipping e-waste to China is ten times cheaper than keeping it in the US. (Source). Huang Xihua, vice-director of the Environmental Protection Bureau in Guangdong explains: "the law is weakly implemented at lower levels (here) because it all depends on the awareness of the local leaders. If they receive no government funding, they have to resort to dirty industry: putting GDP growth ahead of the environment." The value of parts in discarded electronics provides an incentive for poverty-stricken citizens to migrate to Guiyu from other provinces to work in processing it. Even still, the average worker, adult or child, makes barely US \$1.50 a day (17 cents an hour). The average workday is sixteen hours.

This \$1.50 is made by recovering the valuable metals and parts that are within the piles of discarded electronics. Even this relatively tiny profit is enough motivation for workers to risk their health for. "About 800 yuan (\$100 US) for a laptop; 600 yuan (\$75 US) for a desktop; 1000 yuan (\$125 US) for a Xerox machine-- isn't that tempting?" processing worker Cao said.

## **Agriculture**

Once a rice village, the pollution has made Guiyu unable to produce crops for food and the water of the river undrinkable.

## **Media coverage**

Guiyu as an e-waste hub was first documented fully in December 2001 by the Basel Action Network, a non-profit organization which combats the practice of toxic waste export to developing countries in their report and documentary film entitled *Exporting Harm*. The health and environmental issues exposed by this report and subsequent scientific studies have greatly concerned international organisations such as the Basel Action Network and later Greenpeace and the United Nations Environment Programme and the Basel Convention. Media documentation of Guiyu is tightly regulated by the Chinese government, for fear of exposure or legal action. For example, a November 2008 news story by 60 Minutes, a popular US TV news program, documented the illegal shipments of electronic waste from recyclers in the US to Guiyu. While taping part of the story on-site at an illegal recycling dump in Guiyu, representatives of the Chinese recyclers attempted without success to confiscate the footage from the 60 Minutes TV crew. . "They're afraid of being found out. This is smuggling. This is illegal," says Jim Puckett, founder of the Basel Action Network. "A lot of people are turning a blind eye here. And if somebody makes enough noise, they're afraid this is all going to dry up." Greenpeace has taken action against the environmental injustice of the situation in Guiyu- using different methods to raise awareness such as building a statue using e-waste collected from a site in Guiyu, or delivering a truckload of e-waste dumped in Guiyu back to Hewlett Packard headquarters. Greenpeace has been lobbying large consumer electronics companies to stop using toxic substances in their products, with varying degrees of effectiveness. Activism from the United States has become vital in the movement to halt the electronic waste dumping in Guiyu because of the citizens' lack of resources to organize and act themselves. As awareness spreads, many more journalists travel to the region, producing shocking photos and videos- for example, TIME magazine ran a feature issue on China's Electronic Waste Village using photographs only.

## **Clean up efforts**

Since 2007, conditions in Guiyu have changed little despite the efforts of the central government to crack down and enforce the long-standing e-waste import ban. Recent studies have revealed some of the highest levels of dioxin ever recorded. However, because of the work of activist groups and increasing awareness of the situation, there is

hope for the site to be improved. "It can be done. Look at what happened with lead acid batteries. We discovered they were hazardous, new legislation enforced new ways of dealing with the batteries which led to an infrastructure being created. The key was making it easy for people and companies to participate. It took years to build. E-waste is going the same route. But attitudes have changed and we will get there," Mr. Houghton says. Zheng Songming, head of the Guiyu Township government has published a decree to ban burning electronics in fires and soaking them in sulfuric acid, and promises supervision and fines for violations. Over 800 coal-burning furnaces have been destroyed because of this ordinance, and most notably, air quality has returned to Level II, now technically acceptable for habitation.

Guiyu in Guangdong Province is the location of the largest electronic waste site on earth.

## **Legislation**

Chinese laws are primarily concerned with eliminating the import of e-waste. China has ratified the Basel Convention as well as the Basel Ban Amendment, officially banning the import of e-waste. In October 2008, The Chinese State Council also approved a "draft regulation on the management of electronic waste." This regulation is intended to promote the continued use of resources through recycling and to monitor the end-of-life treatment of electronics. Under the new regulations, recycling of electronics by the consumer is mandated. It also requires the recycling of unnecessary materials discarded in the manufacturing process.

Hong Kong's Waste Disposal Ordinance bans the import of batteries and cathode rays. There is not currently legislation in place to bar the entrance of other electronics into the ports of Hong Kong.

Chinese laws are primarily concerned with eliminating the import of e-waste. China has ratified the Basel Convention as well as the Basel Ban Amendment, officially banning the import of e-waste. In October 2008, The Chinese State Council also approved a "draft regulation on the management of electronic waste." This regulation is intended to promote the continued use of resources through recycling and to monitor the end-of-life treatment of electronics. Under the new regulations, recycling of electronics by the consumer is mandated. It also requires the recycling of unnecessary materials discarded in the manufacturing process.

### **Japan**

Japan has been a leader in technological advances for decades and now they are among the leaders in creating ways to deal with the resulting waste. Since 1970, Japan has been treating the waste of electronic materials differently than other materials. They would hire specially trained workers to dismantle and recycle the material. Unfortunately, the cost grew too great to keep these workers around. Instead, electronic waste was treated as every other form of waste, and tossed into a giant landfill. Waste landfills are a huge problem for any country and in Japan it was no different.

Recently, two laws have come in effect in Japan to reduce both the landfill problem and the electronic waste problem. The first law is the Law for the Promotion of Effective Utilization of Resources (LPUR). This law encourages manufacturers to voluntarily help with the recycling of goods and reducing the generation of the waste in general. The second law is the Law for the Recycling of Specified Kinds of Home Appliances (LRHA). This law imposes more obligations on the recycling efforts of both consumers and manufacturers of used home appliances. There are taxes that were instated after October, 2003 that made it so any computer purchased after that date had them. If a computer was purchased before that date, than those wanting to recycle their computer would pay a nominal fee to keep up with recycling costs.

The utilization of electronic waste resources is around 50% currently and is growing. The LRHA states that consumers are responsible for the cost of recycling most home appliances. This includes transportation costs, and recycling fees. The consumers pay the retailers who will pick it up and recycle it for them and the consumers pay the fees involved in that. In order to make this a somewhat fair system, if a consumer asks a retailer to take the used home appliance for any reason (most likely because they purchased a new appliance), the retailer is obligated to come pick it up. These retailers usually take it back to the manufacturer. The manufacturer is required to have a system in place to recycle this electronic waste, and this system must also maintain a certain percentage of utilization from these resources. There is a part of this process that is not regulated by the government. The process of acquiring a recycling facility and/or how the recycling is currently done. Manufacturers can hire anyone they want to create the facility and they can also recycle electronic waste in any way they deem possible. The only thing it must maintain is the amount of utilization from each material that comes into the facility. Unfortunately, this poses a problem because clearly the manufacturer wants to recycle the products in the cheapest way possible which leaves a lot of room for improvement.

## **Australia**

Electronic waste has been on the agenda of the Australian Federal Government since the mid 1990s. The Australian and New Zealand Environment and Conservation Council (now replaced by the Environment Protection and Heritage Council (EPHC)) was the first body to identify electrical and electronic waste as a concern. In 2002, the EPHC again declared that e-waste needed action. The Electrical Equipment Product Stewardship Sub-Group examined the issue and decided that computer and television waste were 'wastes of concern'. Since that time the television and computer industry has been working with the EPHC to identify a suitable way to manage end-of-life televisions and computers.

In November 2008 the EPHC committed to the development of a national solution to the issue of managing television and computer waste. This action culminated in the release of a package of documents designed to enable public consultation on the various options for managing end-of-life televisions and computers on 16 July 2009. The main document in the package is the Consultation Regulatory Impact Statement: Televisions and Computers. The paper canvasses various options for managing end-of-life units and

analyses the costs and benefits of each. The Consultation Paper does not have a preferred option. The preferred option will be developed by government through the public consultation process prior to the next meeting of the EPHC on 5 November 2009 in Perth where State and Federal Minister will adopt a position.

A series of public meetings were held in Adelaide, Perth, Sydney and Melbourne to receive feedback to the government's proposals. The meetings occurred in late July and early August 2009.

### Product Stewardship

Product Stewardship Australia (PSA) is a not-for-profit organisation established by the television industry in Australia to lead the way in developing recycling programs for e-waste in Australia, particularly televisions. PSA works closely with both State and Federal Governments along with other industry associations to advance product stewardship in Australia. PSA has contributed to the development of the Consultation Regulatory Impact Statement on Televisions and Computers.

### Canada

In February 2004, a fee similar to the one in California was added to the cost of purchasing new televisions, computers, and computer components in Alberta, the first of its kind in Canada. Saskatchewan also implemented an electronics recycling fee in February 2007, followed by British Columbia in August 2007, Nova Scotia in February 2008, and Ontario in April 2009. In 2007, Manitoba issued the Proposed Electrical and Electronic Equipment Stewardship Regulation by which the sale of regulated products is forbidden unless covered by the stewardship program. "Products covered under this legislation include TVs, computers, laptops, and scanners." Recycling regulation passed in Ontario in October 2004, requires producers to "either develop product stewardship plans or comply with a product stewardship program for specific products."

### Europe

Some European countries implemented laws prohibiting the disposal of electronic waste in landfills in the 1990s. "This created an e-waste processing industry in Europe."

In Switzerland, the first electronic waste recycling system was implemented in 1991, beginning with collection of old refrigerators. Over the years, all other electric and electronic devices were gradually been included in the system. Legislation followed in 1998, and since January 2005 it has been possible to return all electronic waste to the sales points and other collection points free of charge. There are two established producer responsibility organizations: SWICO, mainly handling information, communication, and organization technology, and SENS, responsible for electrical appliances. The total amount of recycled electronic waste exceeds 10 kg per capita per year.

Additionally, the European Union has implemented several directives and regulations that place the responsibility for “recovery, reuse and recycling” on the manufacturer.

The Waste Electrical and Electronic Equipment Directive (WEEE Directive), as it is often referred to, has now been transposed in national laws in all member countries of the European Union. It was designed to make equipment manufacturers financially or physically responsible for their equipment at the end of its life, under a policy known as Extended producer responsibility (EPR). "Users of electrical and electronic equipment from private households should have the possibility of returning WEEE at least free of charge", and manufacturers must dispose of it in an environmentally friendly manner, by ecological disposal, reuse, or refurbishment. EPR is seen as a useful policy as it internalizes the end-of-life costs and provided a competitive incentive for companies to design equipment with fewer costs and liabilities when it reached its end of life. However, the application of the WEEE Directive has been criticized for implementing the EPR concept in a collective manner, and thereby losing the competitive incentive of individual manufacturers to be rewarded for their green design. Since August 13, 2005, electronics manufacturers have become financially responsible for compliance to the WEEE Directive. Under the directive, each country recycles at least 4 kg of electronic waste per capita per year. Furthermore, the Directive should “decrease e-waste and e-waste exports.”. In December 2008 a draft revision to the Directive proposed a market-based goal of 65%, which is 22 kg per capita in the case of the United Kingdom. A decision on the proposed revisions could result in a new WEEE Directive by 2012.

The Directive on the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment (2002/95/EC), commonly referred to as the Restriction of Hazardous Substances Directive (RoHS Directive), was also adopted in February 2003 by the European Union. The RoHS Directive took effect on July 1, 2006, and is required to be enforced and become law in each member state. This directive restricts the use of six hazardous materials in the manufacture of various types of electronic and electrical equipment.

The Battery Directive enacted in 2006 regulates the manufacture, disposal and trade of batteries in the European Union.

## **New Zealand**



An electronic waste stockpile in Christchurch (2004).

Electronic waste in New Zealand is an environmental issue being addressed by community and government initiatives.

## **Background**

In 2006 there was an estimated 3.4 million televisions, 3.3 million mobile phones, 1.9 million computers and monitors, and 600,000 laptops. In the same year a survey showed that two thirds of respondents were willing to pay for safe disposal of electronic waste such as televisions and computers. The remainder were unwilling to pay anything or were unsure. The survey also showed that 85% were willing to take items to a neighbourhood collection point.

## **eDay**



Electronic waste being collected during eDay in Dunedin, 2008



The eDay logo.

**eDay** is an annual New Zealand initiative, started by Computer Access New Zealand (CANZ), aimed to raise awareness of the potential dangers associated with electronic waste and to offer the opportunity for such waste to be disposed of in an environmentally friendly fashion.

## **History**



eDay in Dunedin, 2008

eDay was first held in Wellington in 2006, as a pilot sponsored by Dell, the event bought in 54 tonnes (120,000 lb) of old computers, mobile phones and other non-biodegradable electronic material. In 2007 the initiative was extended to cover 12 locations, which resulted in it becoming a national initiative, 946 tonnes (2,090,000 lb) were collected.

eDay 2008 was held on October 4 and extended to 32 centres. In 2009 an estimated 966 tonnes (2,130,000 lb) was collected at 38 locations around the country.

## **Purpose**

The initiative was started to minimise the amount of electronic waste being disposed on in landfills, based on evidence from reports that there was an estimated 16 million electronic devices in use in New Zealand and that 1 million new devices were being introduced every year, the report found that the majority of these devices were being disposed in landfills rather than being recycled. A separate report found that half of New Zealand schools did not recycle outdated and replaced equipment, opting instead to deposit it in landfills. When disposed in landfills there is a possibility of the harmful chemicals in the electronic equipment, such as mercury, lead and cadmium, contaminating groundwater and coming into contact with humans or animals, the toxins in the chemicals are capable of causing serious health issues, such as nervous system and brain damage. When recycled, the chemicals are disposed of safely and potentially valuable parts can be reused.

## Initiative



In Christchurch, the 2009 event was held at the Canterbury Agricultural Park.

On the day, drive-thru collection points are established and volunteers operate each centre. Businesses, schools and the public are encouraged to dispose of old computer hardware, mobile phones and printer cartridges. As well as collecting material, the initiative is also designed to increase awareness about the harmful effects of electronic waste.

## Acclaim

CANZ were awarded the New Zealand Ministry for the Environment 2008 Green Ribbon Award for Community action and involvement.

In 2009 CANZ won the Outstanding Industry Initiative in the PricewaterhouseCoopers Hi-Tech Awards.

eDay is a nationwide collection programme for electronic waste which started in 2006. A total of 54 tonnes was collected in the first year of operation and by 2009 this had risen to 946 tonnes.

## Legislation

New Zealand signed the Basel Convention in 1989 and ratified it in 1994. The Basel Convention is an international treaty to reduce the movements of hazardous waste between nations, and specifically to prevent transfer of hazardous waste from developed to less developed countries. Electronic waste can be of a type defined under the convention.

It was not until 2006 that the first application was made for export of hazardous waste under the Basel Convention.

## **Government initiatives**

In 2010 the government put \$750,000 towards the eDay event which is to be held in 40 different locations. Another \$400,000 was allocated towards setting up collection depots and recycling centres around New Zealand.

### **United States**



Computer monitors being packed for shipping.

**Electronic waste** in the **United States** is being addressed with regulations at a state and federal level.

Ninety percent of US e-waste is exported to China and Nigeria.

## **Legislation**

### **Federal**

The United States Congress considers a number of electronic waste bills, including the National Computer Recycling Act introduced by Congressman Mike Thompson (D-CA). Meanwhile, the main federal law governing solid waste is the Resource Conservation and Recovery Act of 1976. It covers only CRTs, though state regulations may differ. There are also separate laws concerning battery disposal. Several trade organizations including the Consumer Electronics Association are lobbying for the implementation of comprehensive federal laws. On March 25, 2009, the House Science and Technology Committee approved funding for research on reducing electronic waste and mitigating environmental impact, regarded by sponsor Ralph Hall (R-TX) as the first federal bill to

address electronic waste directly. On July 6, 2009, Senator Amy Klobuchar (D-MN) and Senator Kristen Gillibrand (D-NY) proposed the "Electronic Device Recycling Research and Development Act". Bill S.1397 not only focuses on stopping illegal e-waste dumping, but it also calls for sustainable design of electronic equipment as well as offers funding for research and development of more sustainable designs, which would reduce the amount of toxic waste and increase the reuse and recycling of electronic products.

During Earth Day, April 22, 2009, two bills were passed by the House of Representatives: H.R. 1580 Electronic Device Recycling Research and Development Act, introduced by Rep. Bart Gordon on March 18, 2009, and H.R. 957 Green Energy Education Act, introduced by Rep. Michael McCaul (R-TX.) H.R. 1580 requires the Administration of Environmental Protection Agency (EPA) to give merit-based grants to consortia of universities, government labs and private industries to conduct research with the purpose of finding new approaches to recycling and reduction of hazardous materials in electronic devices and to "contribute to the professional development of scientists, engineers, and technicians in the field of electronic device manufacturing, design, refurbishing, and recycling." The bill will require the recipients of the grants to report every two years to Congress about the progress of their research, gaps in the advancement, risks and regulatory barriers that might hinder their progress. The Congressional Budget Office estimates that to put the bill in effect "would cost \$10 million in 2010 and \$80 million over the 2010-2014 period." The other bill passed, H.R. 957, authorizes the Department of Energy in partnership with the National Science Foundation to provide grants to Institutions of higher education to promote education and training for Engineers and Architects "in high energy and high-performance building design."

## **State**

A policy of "diversion from landfill" has driven legislation in many states requiring higher and higher volumes of electronic waste to be collected and processed separate from the solid waste stream.

In 2001, Arkansas enacted the Arkansas Computer and Electronic Solid Waste Management Act, which requires that state agencies manage and sell surplus computer equipment, establishes a computer and electronics recycling fund, and authorizes the Department of Environmental Quality to regulate and/or ban the disposal of computer and electronic equipment in Arkansas landfills.

California was the first state to legislate around the issue of e-waste. It implemented a broader waste ban, with advance recovery fee funding in 2003. Electronic waste in California may neither be disposed of in a landfill nor be exported overseas. The 2003 Electronic Waste Recycling Act in California introduced an Electronic Waste Recycling Fee on all new monitors and televisions sold to cover the cost of recycling. The fee ranges from six to ten dollars. California went from only a handful of recyclers to over 60 within the state and over 600 collection sites. The amount of the fee depends on the size of the monitor; it was adjusted on July 1, 2005 in order to match the real cost of

recycling. Cellphones are "considered hazardous waste" in California; many chemicals in cellphones leach from landfills into the groundwater system.

Colorado legislation requires education programs that address its electronic waste problem.

In 2004, Maine passed Maine Public Law 661, An Act to Protect Public Health and the Environment by Providing for a System of Shared Responsibility for the Safe Collection and Recycling of Electronic Waste. It necessitates that after 2006, computer manufacturers take responsibility for handling and recycling computer monitors, and pay the handling costs as well.

Massachusetts was the first of the United States to make it illegal to dispose of CRTs in landfills in April 2000, most similar to the European disposal bans of the 1990s.

Minnesota enacted a law making vendors responsible for the disposal of their branded electronics. Minnesota legislation also outlaws the dumping of cathode ray tubes in landfills.

A law in the state of Washington took effect on January 1, 2009, requiring manufacturers of electronic goods to pay for recycling, and establishing a statewide network of collection points. The program, called E-Cycle Washington, is managed by the Department of Ecology and the Washington Materials Management & Financing Authority.

On January 28, 2010, Arizona introduced HB 2614, a producer responsibility law modeled on the Oregon law that would have covered computers, laptops and TV monitors for recycling. However, it was withdrawn on January 10, 2010.

As of 2008, 17 states have producer responsibility laws in some form. In all, 35 states have or are considering electronic waste recycling laws.

<b>Location</b>	<b>Date signed into law</b>	<b>Legislation</b>
Arkansas	2003	Arkansas Computer and Electronic Solid Waste Management Act
California	2003	Electronic Waste Recycling Act Cell Phone Takeback and Recycling Rechargeable Battery Takeback and Recycling
Colorado	July 2007	National Computer Recycling Act Cell Phone Takeback and Recycling

		Rechargeable Battery Takeback and Recycling
Connecticut	July 2007	CT Electronic Recycling Law
Hawaii	July 2008	Hawaii Electronic Device Recycling Program
Illinois	September 2008	Electronic Products Recycling and Reuse Act
Indiana	May 2009	Amendment to Indiana environmental law
Maine	2004	§1610. Electronic waste An Act To Protect Public Health and the Environment by Providing for a System of Shared Responsibility for the Safe Collection and Recycling of Electronic Waste
Maryland	2005	Maryland's Statewide Electronics Recycling Program
Michigan	May 2007	SB No. 897
Minnesota	December 2008	Minnesota's Electronics Recycling Act
Missouri	June 2008	Manufacturer Responsibility and Consumer Convenience Equipment Collection and Recovery Act
New Jersey	December 2008	Act No. 394
New York City	April 2008, vetoed overrode by council May 2008	INT 728 INT 729
North Carolina	August 2007 amended to add TVs August 2008	S1492 (2007) H819 (2008 Amendment)]
Oklahoma	May 2008	Oklahoma Computer Equipment Recovery Act

Oregon	June 2007	House Bill 2626
Rhode Island	June 2008	Electronic Waste Prevention, Reuse, and Recycling Act
Texas	June 2007	House Bill 2714
Virginia	March 2008	Computer Recovery and Recycling Act.
Washington	March 2006	SB 6428
West Virginia	March 2008	SB 746
Wisconsin	October 2009	SB 107

## Consumer recycling

Consumer recycling options include donating equipment directly to organizations in need, sending devices directly back to their original manufacturers, or getting components to a convenient recycler or refurbisher.

### Donation

Consumer recycling includes a variety of donation options, such as charities which may offer tax benefits. The U.S. Environmental Protection Agency maintains a list of electronic recycling and donation options for American consumers. The National Cristina Foundation, Tech Soup (the Donate Hardware List), the Computer Takeback Campaign, and the National Technology Recycling Project provide resources for recycling. However, local recycling sites that do not process waste products on site, and consumers that throw electronics in the trash, still contribute to electronic waste.

### Takeback

Individuals looking for environmentally-friendly ways in which to dispose of electronics can find corporate electronic takeback and recycling programs across the country. Corporations nationwide have begun to offer low-cost to no-cost recycling, open to the public in most cases, and have opened centers nationally and in some cases internationally. Such programs frequently offer services to take back and recycle electronics, including mobile phones, laptop and desktop computers, digital cameras, and home and auto electronics. Companies such as Staples, Toshiba, and Gateway offer takeback programs that provide monetary incentives for recyclable and/or working technologies. The Manufacturers Recycling Management Co. was founded by Panasonic, Sharp Corporation, and Toshiba to manage electronic waste branded by these manufacturers, including 750 tons of TVs, computers, audio equipment, faxes, and components in its first four months. Office Depot lets customers obtain "tech recycling"

boxes for e-waste if not eligible for the EcoNEW tech trade-in program. Best Buy offers a similar program for products which were purchased at Best Buy. Exceptions exist in some states, which allow for the trade-in of electronics which were not purchased at Best Buy.

Though helpful to both the environment and its citizens, there are some downsides to such programs. Many corporations offer services for a variety of electronic items, while their recycling centers are few in number. Recycling centers and takeback programs are available in many parts of the country, but the type and amount of equipment to be recycled tends to be limited. Some corporations, like Sony in its Take Back Recycling Program, provide recycling incentives but only accept up to five recycled items per day and only if they are that corporation's products. Sony also partners with the Waste Management Inc. Recycle America program and offers discounts and tradeup programs. Costco, which offers free shipping and handling for all recycled pieces of equipment, will only allow Costco club members to participate in their programs. Crutchfield Electronics offers its own gift cards in exchange for electronic waste, through Consumer Electronics Exchange. Hewlett-Packard has recycled over 750 million pounds of electronic waste globally, including hardware and print cartridges.

## **Lobbying**

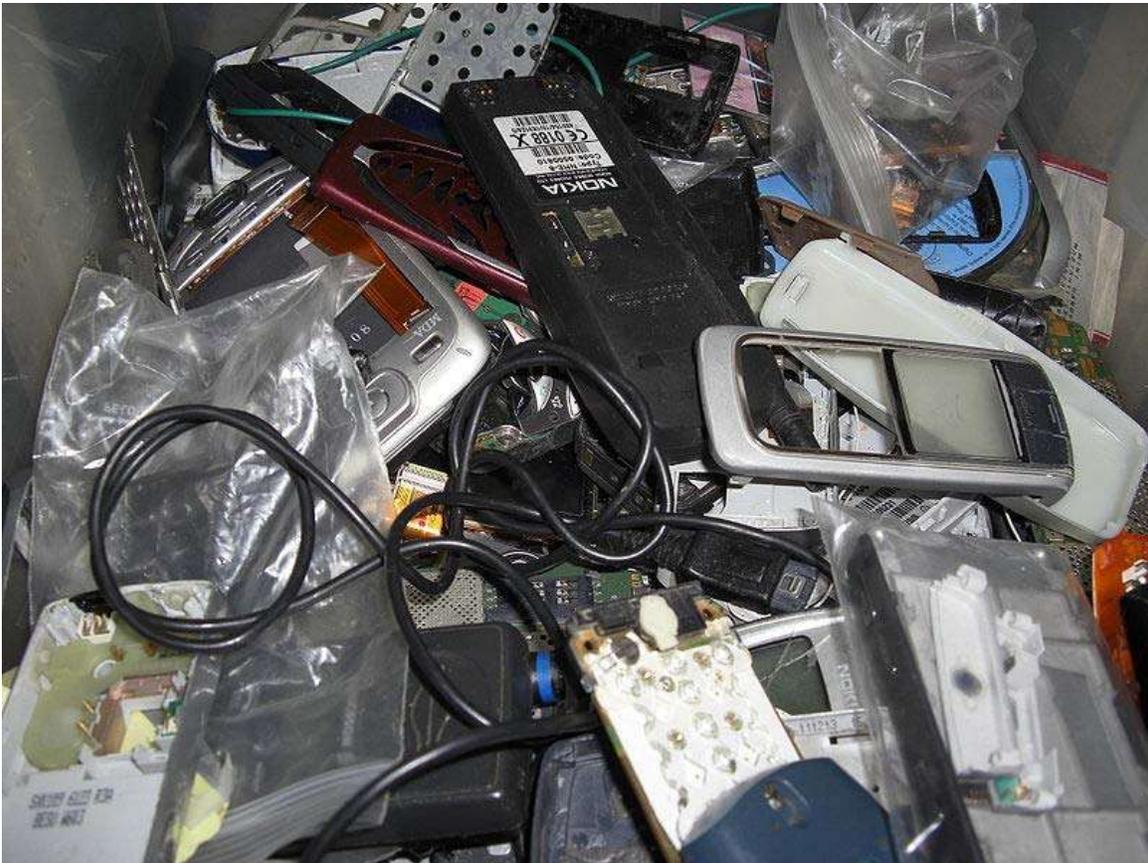
Various organizations actively lobby government in order to address electronic waste issues. The major organisations are the Basel Action Network and the Silicon Valley Toxics Coalition.

## **Reuse**

Free Geek is a collectively run non-profit organization started in Portland, Oregon. It has two central goals: to reuse or recycle used computer equipment that might otherwise become hazardous waste, and to make computer technology more accessible to those who lack financial means or technical knowledge.

ReCellular, Inc. and GreenCells are organizations that buy and resell used, refurbished or discontinued cell phones, to help reduce electronic waste.

# Mobile Phone Recycling



Scrapped mobile phones.

The ubiquitous mobile phone is able to be recycled at the end of its life.

Rapid technology change, low initial cost, and even planned obsolescence have resulted in a fast-growing surplus, which contributes to the increasing amount of electronic waste around the globe. Recyclers consider electronic waste a "rapidly expanding" issue. In the

United States, an estimated 70% of heavy metals in landfills comes from discarded electronics, while electronic waste represents only 2% of America's trash in landfills.

While some recycle, 7% of mobile phone owners still throw away their old phones. Mobile phones are "considered hazardous waste" in California; many chemicals in such phones leach from landfills into the groundwater system. Environmental advocacy group Greenpeace claims that the soldering of the iPhone battery into its handset hinders its being recycled. It also states that its scientists found toxic phthalates on iPhone cables, and it holds that this contravenes California's Proposition 65, which requires warning labels on products exposing consumers to phthalates.

Because the United States has not ratified the Basel Convention or its Ban Amendment, and has no domestic laws forbidding the export of toxic waste, the Basel Action Network estimates that about 80% of the electronic waste directed to recycling in the U.S. does not get recycled there at all, but is put on container ships and sent to countries such as China. Guiyu in the Shantou region of China, and Delhi and Bangalore in India, have electronic waste processing areas.

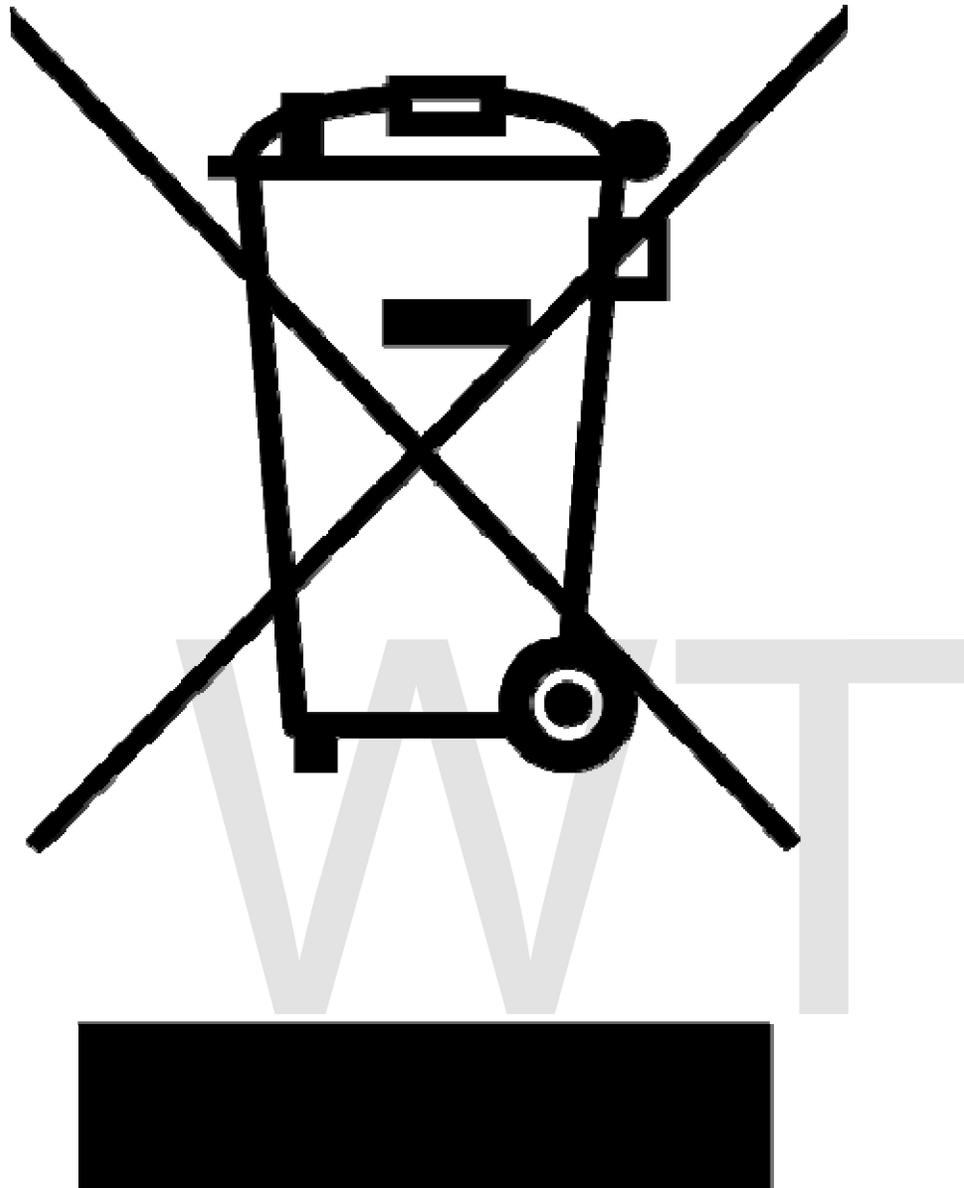
## **Regulation**

The regulation governing mobile phones in the European Union is the Waste Electrical and Electronic Equipment Directive, implemented in 2003 (WEEE Directive, 2002/96/EC). It was intended to make equipment manufacturers financially or physically responsible for their equipment at the end of its life, under a policy known as extended producer responsibility (EPR).

In Switzerland, an early electronic waste recycler, it is possible to return surplus mobile phones to the sales points and other collection points free of charge. SWICO is the established Producer Responsibility Organisation.

The main United States law governing solid waste is the Resource Conservation and Recovery Act of 1976, which covers only cathode ray tubes. No federal standard covering smartphones or electronic waste has arisen, although the U.S. Congress considers bills like the National Computer Recycling Act introduced by Congressman Mike Thompson (D-CA), and state regulations differ widely.

# **Waste Electrical and Electronic Equipment Directive**



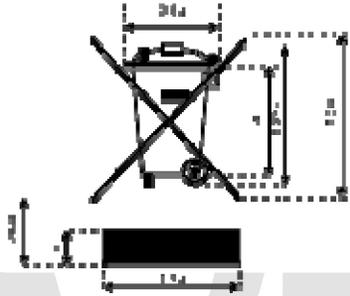
The WEEE symbol.

The **Waste Electrical and Electronic Equipment Directive** (WEEE Directive) is the European Community directive 2002/96/EC on waste electrical and electronic equipment (WEEE) which, together with the RoHS Directive 2002/95/EC, became European Law in February 2003, setting collection, recycling and recovery targets for all types of electrical goods.

The directive imposes the responsibility for the disposal of waste electrical and electronic equipment on the manufacturers of such equipment. Those companies should establish an infrastructure for collecting WEEE, in such a way that "Users of electrical and electronic equipment from private households should have the possibility of returning WEEE at least free of charge". Also, the companies are compelled to use the collected waste in an

ecologically-friendly manner, either by ecological disposal or by reuse/refurbishment of the collected WEEE.

The WEEE Directive obliged the twenty-five EU member states to transpose its provisions into national law by 13 August 2004. Only Cyprus met this deadline. On 13 August 2005, one year after the deadline, all member states except for Malta and the UK had transposed at least framework regulations. As the national transposition of the WEEE Directive varies between the member states, a patchwork of requirements and compliance solutions is emerging across Europe.



Construction sheet for the WEEE crossed-out wheelie bin logo.

In a bid to emphasise the importance of this directive, in April 2005 the Royal Society of Arts in the UK (in conjunction with Canon) unveiled a 7 metre tall sculpture entitled 'WEEE Man' on London's South Bank, made from 3.3 tonnes of electrical goods - the average amount of electrical waste one UK individual creates in a lifetime. The giant figure was subsequently moved to the Eden Project in Cornwall as part of a UK tour.

# Computer Recycling



Computer monitors are typically packed into low stacks on wooden pallets for recycling and then shrink-wrapped.

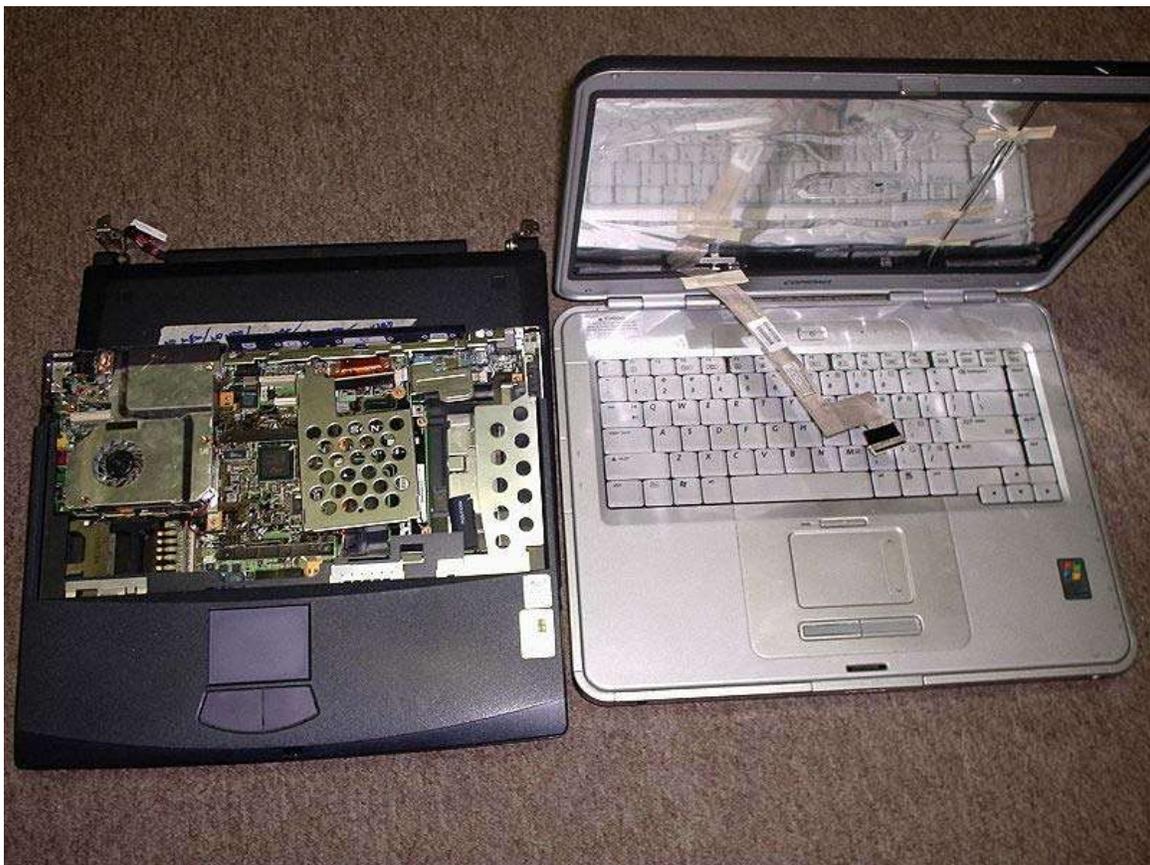
**Computer recycling** or **Electronic recycling** is the recycling or reuse of computers or other electronics. It includes both finding another use for materials (such as donation to charity), and having systems dismantled in a manner that allows for the safe extraction of the constituent materials for reuse in other products.

## Reasons for recycling

Obsolete computers or other electronics are a valuable source for secondary raw materials, if treated properly; if not treated properly, they are a source of toxins and carcinogens. Rapid technology change, low initial cost, and even planned obsolescence have resulted in a fast-growing surplus of computer or other electronic components around the globe. Technical solutions are available, but in most cases a legal framework, a collection system, logistics, and other services need to be implemented before a technical solution can be applied. According to the U.S. Environmental Protection Agency, an estimated 30 to 40 million surplus PCs, which it classifies under the term "hazardous household waste", will be ready for end-of-life management in each of the next few years. The U.S. National Safety Council estimates that 75% of all personal computers ever sold are now surplus electronics.

In 2007, the United States Environmental Protection Agency (EPA) said that more than 63 million computers in the U.S. were traded in for replacements—or they simply were discarded. Today 15 percent of electronic devices and equipment are recycled in the United States. Most electronic waste is sent to landfills or becomes incinerated, having a negative impact on the environment by releasing materials such as lead, mercury, or cadmium into the soil, groundwater, and atmosphere.

Many materials used in the construction of computer hardware can be recovered in the recycling process for use in future production. Reuse of tin, silicon, iron, aluminum, and a variety of plastics — all present in bulk in computers or other electronics — can reduce the costs of constructing new systems. In addition, components frequently contain copper, gold, and other materials valuable enough to reclaim in their own right.



Dismantled Sony Vaio PCG-982L and Compaq JBL Professional laptops.

Computer components contain valuable elements and substances suitable for reclamation, including lead, copper, and gold. They also contain many toxic substances, such as dioxins, polychlorinated biphenyls (PCBs), cadmium, chromium, radioactive isotopes, and mercury. A typical computer monitor may contain more than 6% lead by weight, much of which is in the lead glass of the cathode ray tube (CRT). A typical 15-inch computer monitor may contain 1.5 pounds of lead, but other monitors have been estimated as having up to 8 pounds of lead. Circuit boards contain considerable

quantities of lead-tin solders and are even more likely to leach into groundwater or to create air pollution via incineration. Additionally, the processing required to reclaim the precious substances (including incineration and acid treatments) may release, generate, and synthesize further toxic byproducts.

A major computer or electronic recycling concern is export of waste to countries with lower environmental standards. Companies may find it cost-effective in the short term to sell outdated computers to less developed countries with lax regulations. It is commonly believed that a majority of surplus laptops are routed to developing nations as "dumping grounds for e-waste". The high value of working and reusable laptops, computers, and components (e.g., RAM) can help pay the cost of transportation for a large number of worthless "commodities". Broken monitors, obsolete circuit boards, and short-circuited transistors are difficult to spot in a containerload of used electronics.

## Regulations



An abandoned Texan monitor.

## Europe

In Switzerland, the first electronic waste recycling system was implemented in 1991, beginning with collection of old refrigerators; over the years, all other electric and electronic devices were gradually added to the system. The established producer responsibility organization is SWICO, mainly handling information, communication, and organization technology.

The European Union implemented a similar system in February 2003, under the Waste Electrical and Electronic Equipment Directive (WEEE Directive, 2002/96/EC).

## **United States**

### **Federal**

The United States Congress considers a number of electronic waste bills, including the National Computer Recycling Act introduced by Congressman Mike Thompson (D-CA). Meanwhile, the main federal law governing solid waste is the Resource Conservation and Recovery Act of 1976. It covers only CRTs, though state regulations may differ. There are also separate laws concerning battery disposal. On March 25, 2009, the House Science and Technology Committee approved funding for research on reducing electronic waste and mitigating environmental impact, regarded by sponsor Ralph Hall (R-TX) as the first federal bill to address electronic waste directly.

### **State**

Many states have introduced legislation concerning recycling and reuse of computers or computer parts or other electronics. Most American computer recycling legislation addresses it from within the larger electronic waste issue.

In 2001, Arkansas enacted the Arkansas Computer and Electronic Solid Waste Management Act, which requires that state agencies manage and sell surplus computer equipment, establishes a computer and electronics recycling fund, and authorizes the Department of Environmental Quality to regulate and/or ban the disposal of computer and electronic equipment in Arkansas landfills.

The recently passed Electronic Device Recycling Research and Development Act distributes grants to universities, government labs, and private industry for research in developing projects in line with e-waste recycling and refurbishment.

### **Asia**

South Korea, Japan, and Taiwan require that sellers and manufacturers of electronics be responsible for recycling 75% of them.

## **Recycling methods**



Computers being collected for recycling at a pickup event in Olympia, Washington, United States.

### **Consumer recycling**

Consumer recycling options include donating computers directly to organizations in need, sending devices directly back to their original manufacturers, or getting components to a convenient recycler or refurbisher. The Computer Takeback Campaign and the Tech Soup Donate Hardware List are resources for locating recyclers and refurbishers.

### **Donation**

Consumer recycling includes a variety of donation options, such as charities which may offer tax benefits. The U.S. Environmental Protection Agency maintains a list of donation options for American consumers.

### **Takeback**

When researching computer companies before a computer purchase, consumers can also find out if they offer recycling services. Most major computer manufacturers offer some form of recycling. At the user's request they may mail in their old computers, or arrange for pickup from the manufacturer.

Hewlett-Packard also offers free recycling, but only one of its "national" recycling programs is available nationally, rather than in one or two specific states. Hewlett-Packard also offers to pick up any computer product of any brand for a fee, and to offer a coupon against the purchase of future computers or components; it was the largest computer recycler in America in 2003, and it has recycled over 750 million pounds of electronic waste globally since 1995. It encourages the shared approach of collection points for consumers and recyclers to meet.

### **Exchange**

Manufacturers often offer a free replacement service when purchasing a new PC. Dell Computers and Apple Inc. will take back old products when one buys a new one. Both refurbish and resell their own computers with a one-year warranty.

Many companies purchase and recycle all brands of working and broken laptops and notebook computers, whether from individuals or corporations. Building a market for recycling of desktop computers has proven more difficult than exchange programs for laptops, smartphones, and other smaller electronics. A basic business model is to provide a seller an instant online quote based on laptop characteristics, then to send a shipping label and prepaid box to the seller, to erase, reformat, and process the laptop, and to pay rapidly by check. A majority of these companies are also generalized electronic waste recyclers as well; organizations that recycle computers exclusively include Cash For Laptops, a laptop refurbisher in Nevada that claims to be the first to buy laptops online, in 2001.

Online auction at eBay is an alternative for consumers willing to resell for cash less fees, in a complicated, self-managed, competitive environment where paid listings might not sell. Craigslist can be similarly risky due to forgery scams and uncertainty.



Bulk laptops at a recycling affiliate, broken down into Dell, Gateway Computers, Hewlett-Packard, Sony, and other.

### **Corporate recycling**

Businesses seeking a cost-effective way to recycle large amounts of computer equipment responsibly face a more complicated process. They also have the option of contacting the manufacturers and arranging recycling options. However, in cases where the computer equipment comes from a wide variety of manufacturers, it may be more efficient to hire a third-party contractor to handle the recycling arrangements.

### **Early pioneering efforts to e-waste**

The first major publication to report the recycling of computers and electronic waste was published on the front page of the New York Times on April 14, 1993 by columnist Steve Lohr.

Professional IT Asset Disposition (ITAD) firms specialize in corporate computer disposal and recycling services in compliance with local laws and regulations and also offer secure data elimination services that comply with data erasure standards. Companies that specialize in data protection and green disposal processes dispose of both data and used equipment while at the same time employing strict procedures to help improve the

environment. Some companies will pick up unwanted equipment from businesses, wipe the data clean from the systems, and provide an estimate of the product's remaining value. For unwanted items that still have value, these firms will buy the excess IT hardware and sell refurbished products to those seeking more affordable options than buying new.

Corporations face risks both for incompletely destroyed data and for improperly disposed computers, and according to the Resource Conservation and Recovery Act, are liable for compliance with regulations even if the recycling process is outsourced. Companies can mitigate these risks by requiring waivers of liability, audit trails, certificates of data destruction, signed confidentiality agreements, and random audits of information security. The National Association of Information Destruction is an international trade association for data destruction providers.

## **Data security**

Data security is an important part of computer recycling. Federal regulations mandate that there are no information security leaks in the lifecycle of secure data; this includes its destruction and recycling. There are a number of federal laws and regulations, including HIPAA, Sarbanes-Oxley, FACTA, GLB, which govern the data lifecycle and require that establishments with high and low-profile data keep their data secure. Recycling computers can be dangerous when handling sensitive data, specifically to businesses storing tax records or employee information. While most people will try to wipe their hard drives clean before disposing of their old computers, only 5 percent rely on an industry specialist or a third party to completely clean the system before it's disposed of according to an IBM survey. Industry standards recommend a 3X overwriting process for complete protection against retrieving confidential information. This means a hard drive must be wiped three times in order to ensure the data cannot be retrieved and possibly used by others.

### **Reasons to destroy and recycle securely**

There are ways to ensure that not only hardware is destroyed but also the private data on the hard drive. Having customer data stolen, lost, or misplaced contributes to the ever growing number of people who are affected by identity theft, which can cause corporations to lose more than just money. The image of a company that holds secure data, such as banks, pharmaceuticals, and credit corporations is also at risk. If a company's public image is hurt that could cause consumers to not use their services and could cost millions in business losses and positive public relation campaigns. The cost of data breaches "var[ies] widely ranging \$90 to \$305 per customer record, depending on whether the breach is "low-profile" or "high-profile" and the company is in a non-regulated or highly regulated area, such as banking." There is also a major backlash from the consumer if there is a data breach in a company that is supposed to be trusted to protect their private information.

### **Secure recycling**

There are regulations that monitor the data security on end-of-life hardware. National Association for Information Destruction (NAID) “is the international trade association for companies providing information destruction services. Suppliers of products, equipment and services to destruction companies are also eligible for membership. NAID's mission is to promote the information destruction industry and the standards and ethics of its member companies.” There are companies that follow the guidelines from NAID and also meet all Federal EPA and local DEP regulations.

The typical process for computer recycling aims to securely destroy hard drives while still recycling the byproduct. A typical process for effective computer recycling accomplishes the following:

1. Receive hardware for destruction in locked and securely transported vehicles
2. Shred hard drives
3. Separate all aluminum from the waste metals with an electromagnet
4. Collect and securely deliver the shredded remains to an aluminum recycling plant
5. Mold the remaining hard drive parts into aluminum ingots

WWT

# Plastic Recycling

**Plastic recycling** is the process of recovering scrap or waste plastics and reprocessing the material into useful products, sometimes completely different in form from their original state. For instance, this could mean melting down soft drink bottles and then casting them as plastic chairs and tables. Typically a plastic is not recycled into the same type of plastic, and products made from recycled plastics are often not recyclable.

## Challenges

When compared to other materials like glass and metal materials, plastic polymers require greater processing to be recycled. Plastics have a low entropy of mixing, which is due to the high molecular weight of their large polymer chains. A macromolecule interacts with its environment along its entire length, so its enthalpy of mixing is large compared to that of an organic molecule with a similar structure. Heating alone is not enough to dissolve such a large molecule; because of this, plastics must often be of nearly identical composition in order to mix efficiently.

When different types of plastics are melted together they tend to phase-separate, like oil and water, and set in these layers. The phase boundaries cause structural weakness in the resulting material, meaning that polymer blends are only useful in limited applications.

Another barrier to recycling is the widespread use of dyes, fillers, and other additives in plastics. The polymer is generally too viscous to economically remove fillers, and would be damaged by many of the processes that could cheaply remove the added dyes. Additives are less widely used in beverage containers and plastic bags, allowing them to be recycled more frequently.

The use of biodegradable plastics is increasing. If some of these get mixed in the other plastics for recycling, the reclaimed plastic is not recyclable because the variance in properties and melt temperatures.

## Processes

Before recycling, plastics are sorted according to their resin identification code, a method of categorization of polymer types, which was developed by the Society of the Plastics Industry in 1988. Polyethylene terephthalate, commonly referred to as PET, for instance, has a resin code of 1. They are also often separated by colour. The plastic recyclables are then shredded. These shredded fragments then undergo processes to eliminate impurities like paper labels. This material is melted and often extruded into the form of pellets which are then used to manufacture other products.

### Monomer recycling

Many recycling challenges can be resolved by using a more elaborate *monomer recycling* process, in which a condensation polymer essentially undergoes the inverse of the polymerization reaction used to manufacture it. This yields the same mix of chemicals that formed the original polymer, which can be purified and used to synthesize new polymer chains of the same type. Du Pont opened a pilot plant of this type in Cape Fear, North Carolina, USA, to recycle PET by a process of methanolysis, but it closed the plant due to economic pressures.

### Thermal depolymerization

Another process involves the conversion of assorted polymers into petroleum by a much less precise thermal depolymerization process. Such a process would be able to accept almost any polymer or mix of polymers, including thermoset materials such as vulcanized rubber tires and the biopolymers in feathers and other agricultural waste. Like natural petroleum, the chemicals produced can be made into fuels as well as polymers. A pilot plant of this type exists in Carthage, Missouri, USA, using turkey waste as input material. Gasification is a similar process, but is not technically recycling since polymers are not likely to become the result.

### Heat compression

Yet another process that is gaining ground with startup companies (especially in Australia, United States and Japan) is heat compression. The heat compression process takes all unsorted, cleaned plastic in all forms, from soft plastic bags to hard industrial waste, and mixes the load in tumblers (large rotating drums resembling giant clothes dryers). The most obvious benefit to this method is the fact that all plastic is recyclable, not just matching forms. However, criticism rises from the energy costs of rotating the drums, and heating the post-melt pipes.

### Other processes

A process has also been developed in which many kinds of plastic can be used as a carbon source in the recycling of scrap steel.

# Applications

## PET

Post-consumer polyethylenes are sorted into different color fractions, cleaned, and prepared for processing . This sorted post-consumer PET waste is crushed, chopped into flakes, pressed into bales, and offered for sale.

One use for this recycled PET that has recently started to become popular is to create fabrics to be used in the clothing industry . The fabrics are created by spinning the PET flakes into thread and yarn . This is done just as easily as creating polyester from brand new PET . The recycled PET thread or yarn can be used either alone or together with other fibers to create a very wide variety of fabrics. Traditionally these fabrics were used to create strong, durable, rough, products, such as jackets, coat, shoes, bags, hats, and accessories. However, these fabrics are usually too rough on the skin and could cause irritation. Therefore, they usually are not used on any clothing that may irritate the skin, or where comfort is required . But in today's new eco-friendly world there has been more of a demand for “green” products. As a result, many clothing companies have started looking for ways to take advantage of this new market and new innovations in the use of recycled PET fabric are beginning to develop. These innovations included different ways to process the fabric , to use the fabric, or blend the fabric with other materials . Some of the fabrics that are leading the industry in these innovations include Billabong's Eco-Supreme Suede , Livity's Rip-Tide III , Wellman Inc's Eco-fi(formerly known as EcoSpun), and Reware's Rewoven . Some additional companies that take pride in using recycled PET in their products are Crazy Shirts and Playback .

## PVC

PVC- or Vinyl Recycling has historically been difficult to perfect on the industrial scale. But within the last decade several viable methods for recycling or upcycling PVC plastic have been developed.

## HDPE

The most-often recycled plastic , HDPE or number 2, is downcycled into plastic lumber, tables, roadside curbs, benches, truck cargo liners, trash receptacles, stationery (e.g. rulers) and other durable plastic products and is usually in demand.

## Other plastics

The white plastic foam peanuts used as packing material are often accepted by shipping stores for reuse.

Successful trials in Israel have shown that plastic films recovered from mixed municipal waste streams can be recycled into useful household products such as buckets.

Similarly, agricultural plastics such as mulch film, drip tape and silage bags are being diverted from the waste stream and successfully recycled into much larger products for industrial applications such as plastic composite railroad ties. Historically, these agricultural plastics have primarily been either landfilled or burned on-site in the fields of individual farms.

CNN reports that Dr. S. Madhu of the Kerala Highway Research Institute, India has formulated a road surface that includes recycled plastic. Aggregate, bitumen (asphalt) with plastic that has been shredded and melted at a temperature below 220 degrees C (428 °F) to avoid pollution. This road surface is claimed to be very durable and monsoon rain resistant. The plastic is sorted by hand, which is economical in India. The test road used 60 kg of plastic for an approx. 500m long, 8m wide, two-lane road.

## **Financial justification**

In 2008, the price of PET dropped from \$370/ton in the US to \$20 in November. . PET prices had returned to their long term averages by May of 2009.

## **Recycling rates**

Plastic recycling rates lag far behind those of other items, such as newspaper (about 80%) and corrugated fiberboard (about 70%). All plastic bottles were recycled at a rate of 24% in 2005.

The quantity of post-consumer plastics recycled has increased every year since at least 1990. In 2006 the amount of plastic bottles recycled reached a record high of 2.2 trillion pounds. The amount of PET bottles recycled in 2006 increased more than 102 million pounds compared to 2005. HDPE bottle recycling increased in 2005 to 928 million pounds.

## **Consumer education**

### **United States**

Low national plastic recycling rates have been due to the complexity of sorting and processing, unfavorable economics, and consumer confusion about which plastics can actually be recycled. Part of the confusion has been due to the recycling symbol that is usually on all plastic items. This symbol is called a resin identification code. It is stamped or printed on the bottom of containers and surrounded by a triangle of arrows. The intent of these arrows was to make it easier to identify plastics for recycling. The recycling symbol doesn't necessarily mean that the item will be accepted by residential recycling programs.

### **United Kingdom**

In the UK, the amount of post-consumer plastic being recycled is relatively low, due in part to a lack of recycling facilities.

The Plastics 2020 Challenge was founded in 2009 by the plastics industry with the aim of engaging the British public in a nationwide debate about the use, reuse and disposal of plastics, hosts a series of online debates on its website framed around the waste hierarchy.

## Plastic identification code

Seven groups of plastic polymers, each with specific properties, are used worldwide for packaging applications (see table below). Each group of plastic polymer can be identified by its Plastic Identification code (PIC) - usually a number or a letter abbreviation. For instance, Low-Density Polyethylene can be identified by the number 4 and/or the letters "LDPE". The PIC appears inside a three-chasing arrow recycling symbol. The symbol is used to indicate whether the plastic can be recycled into new products.

The PIC was introduced by the Society of the Plastics Industry, Inc. which provides a uniform system for the identification of different polymer types and helps recycling companies to separate different plastics for reprocessing. Manufacturers of plastic products are required to use PIC labels in some countries/regions and can voluntarily mark their products with the PIC where there are no requirements. Consumers can identify the plastic types based on the codes usually found at the base or at the side of the plastic products, including food/chemical packaging and containers. The PIC is usually not present on packaging films, as it is not practical to collect and recycle most of this type of waste.

Plastic Identification Code	Type of plastic polymer	Properties	Common Packaging Applications
	Polyethylene terephthalate (PET, PETE)	Clarity, strength, toughness, barrier to gas and moisture.	Soft drink, water and salad dressing bottles; peanut butter and jam jars
	High-density polyethylene (HDPE)	Stiffness, strength, toughness, resistance to moisture, permeability to gas.	Water pipes, Hula-Hoop (children's game) rings, Milk, juice and water bottles; the occasional shampoo / toiletry bottle



Polyvinyl chloride (PVC)

Versatility, clarity, ease of blending, strength, toughness.

Juice bottles; cling films; PVC piping



Low-density polyethylene (LDPE)

Ease of processing, strength, toughness, flexibility, ease of sealing, barrier to moisture.

Frozen food bags; squeezable bottles, e.g. honey, mustard; cling films; flexible container lids.



Polypropylene (PP)

Strength, toughness, resistance to heat, chemicals, grease and oil, versatile, barrier to moisture.

Reusable microwaveable ware; kitchenware; yogurt containers; margarine tubs; microwaveable disposable take-away containers; disposable cups; plates.



Polystyrene (PS)

Versatility, clarity, easily formed

Egg cartons; packing peanuts; disposable cups, plates, trays and cutlery; disposable take-away containers;



Other (often polycarbonate or ABS)

Dependent on polymers or combination of polymers

Beverage bottles; baby milk bottles; electronic casing.