Cell Phones: An Overview

A cell phone is really a radio. Its predecessor was the radio telephone used in cars — primarily police and other emergency vehicles — beginning in the 1940s in the US. These were serviced by a central antenna in an area with only a few channels* and required high power transmission over long distances. Because of the limited number of channels available, callers typically had to wait — sometimes for long periods — in order to place a call. The equipment was extremely heavy and cumbersome.

The first commercial cell phone services were introduced in the US in 1983, and since then the use of cell phones has skyrocketed. In 1985, the country had 340,000 subscribers. That number increased to 5.3 million by 1990, to 33.8 million by 1995, and to close to 130 million by 2001.[1]

The genius of the cellular system is to divide geographic areas into a network of small cells, making hundreds of frequencies available and allowing millions of people to use the system simultaneously. And because only low power transmission is required, phone batteries can be small. These factors, and the continually shrinking size and weight of electronic components over the past three decades, combined to make widespread use of portable cell phones a reality by the 1990s.

The terminology relating to cell phones can be very confusing, partly because different terms are used in different countries. For example, what Americans call "cell phones" the British call "mobiles" and the French often call "portables." In this report, cell phone refers to both cellular phones and phones that are a component of systems technically distinct from conventional cellular, such as personal communications systems (PCS) in the US. It should also be noted that cell or mobile phones are different from cordless phones. The latter are used to extend wired phone systems over short distances (e.g., under 500 feet within a home) by sending signals between a dedicated base station and a handset. This report does not address cordless phones.

Cell Phone Market Share

The US cell phone market is very competitive. Table 1.1 shows the market share and number of subscribers of the major service providers. Verizon leads with 29 million subscribers. Table 1.2 shows the global market share of the top cell phone manufac-

Table 1.1 Market Share of US Wireless Service Providers, Dec. 31, 2001

	No. of Subscribers (millions)	Market Share (%)
Verizon	29.4	22.8
Cingular	21.6	16.7
AT&T	18.1	14.0
Sprint PCS	13.6	10.5
Nextel	8.6	6.7
VoiceStream	6.9	5.3
Other	31.0	23.9
TOTAL	**129.2**	**100.0**

Source: Strategy Analytics, *Wall Street Journal*, Feb. 12, 2002.

* A channel is a pair of radio frequencies — one to receive and one to transmit signals. The Federal Communications Commission (FCC) assigns commercial and noncommercial licenses giving the right to transmit over specific frequencies.

turers. Positions shift frequently, but in 2001 Nokia was the leader, with 36 percent.

Table 1.2 Global Market Share of Cell Phone Manufacturers, 2001

	No. of Shipments (millions)	Market Share (%)
Nokia	140.0	36
Motorola	58.6	15
Samsung	28.6	7
Siemens	28.4	7
Ericsson	27.9	7
Other	109.5	28
TOTAL	**393.4**	**100.0**

Source: Williams Capital Group, *Barron's*, Feb. 18, 2002.

Cell Phone Standards

All wireless services use a cellular-like network of base stations and antennas, along with mobile switches to manage the network. However, different systems may employ one of several cellular standards, which are not compatible. These standards dictate how a specific system works. They set the rules followed by the various elements of the system – base stations, mobile switches, cellular databases, etc. – in order to communicate with each other.[2]

In the early 1980s, European wireless companies and government officials, with leadership from Scandinavia, agreed to use a single technical standard known as GSM (Global System for Mobile Communications). GSM is now used by two-thirds of the world's cell phone subscribers in over 130 countries.[3] Because of this uniform standard, European users can operate their cell phones throughout Europe, regardless of provider network, and in other parts of the world where GSM has been adopted.

The US, on the other hand, has several competing standards: CDMA (code division multiple access) is used by Verizon and Sprint; TDMA (time division multiple access) is used by AT&T and Cingular; Nextel has its own proprietary standard; and GSM is used by VoiceStream. (In the US, GSM operates at a higher frequency than in Europe, so GSM phones sold in the US may not be compatible with European GSM phones, and vice versa.) With cell phones typically dedicated to a specific service provider using one or another of these competing standards, US users generally have to purchase a new phone when they change service provider, even when the old phone is still functional.

The percentage of customers who switch service providers to get a better deal is referred to as "churn." The financial magazine *Barron's* estimates churn at nearly 3 percent per month, or over 30 percent per year. This means that about 40 million users are switching service provider each year – and discarding their phones even though they may be in good working order.[4] Moreover, since US phones do not work in most other countries, travelers needing wireless services abroad must buy an additional phone. Thus, the net result of the lack of a single cell phone standard is more phones purchased and more discarded, with obvious implications for waste. (This is one impetus behind the development of a throwaway cell phone, discussed in chapter 7.)

Given the wide reach of the global economy and the huge volume of global travel, the need for a worldwide wireless communications system is clear. Such a system would be greatly facilitated by a single standard, and there have been numerous attempts to develop one. The International Telecommunications Union, a United Nations agency, tried but did not succeed. The Mobile Wireless Internet Forum, a new group that includes all the major companies in the industry, may meet with greater success. However, as the industry upgrades its

technology and moves to the next generation of equipment, competition among supporters of the different standards is intense. The stakes are high – domination of worldwide wireless communication – and companies with the losing standards will be stuck with a lot of obsolete equipment.

A new technology now under development could render the standard issue moot. Software-defined radio (SDR) would shift many of the functions of hardware components to software, allowing for much greater flexibility. With SDR, the software could be reprogrammed to accommodate multiple standards or added applications, allowing cell phones and base stations to be upgraded without changing hardware. However, there are still technical problems to be solved before this technology becomes commercially viable.[5]

Makeup and Environmental Impacts of Cell Phones

Cell phones are complicated devices capable of processing millions of calculations per second. Their basic components are:

- The handset, including –
  - The printed wiring board (PWB).*
  - A liquid-crystal display panel (LCD).
  - The keypad, antenna, speaker, and microphone.
  - The carrying case.
- The power source/batteries.
- An adapter to charge the batteries.

A study done at Delft University of Technology in the Netherlands[6] indicates that the PWB and LCD together account for 98 percent of the handset's environmental impacts in production and recycling. This analysis excludes the impacts of the adapter and batteries, and is based on phones made between 1995 and 1998. The PWB and LCD, responsible for almost all of a handset's environmental impacts, account for only about half its weight.

According to TCO Development (a company owned by the Swedish Confederation of Professional Employers that aims to create good workplace environments through certification and eco-labeling programs), most of the environmental impacts of cell phones are due to the PWB, LCD, and batteries. For a phone to obtain the TCO label, it must be possible to open the unit's housing and separate these three parts using a single tool in a single operation.[7]

The Printed Wiring Board

The printed wiring board is the brains of the cell phone, controlling and coordinating all its functions, from signaling the base station to performing housekeeping chores for the keyboard and display. It is composed of electronic components such as integrated circuits and capacitors connected with circuitry (primarily made of copper) soldered to the board and secured with protective adhesives and coatings. The board itself is usually made of epoxy resins or fiberglass and is generally coated with gold plating.[8]

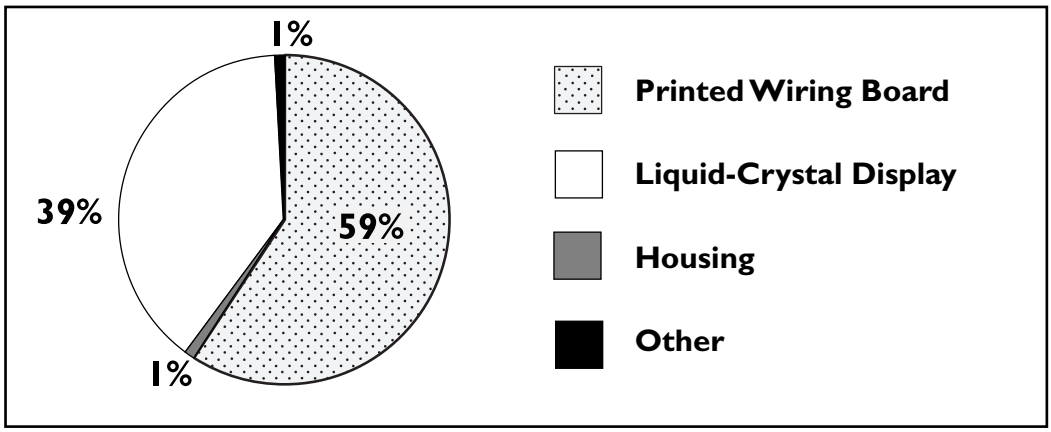
* Printed wiring boards are also known as printed circuit boards (PCBs). In the US, "printed wiring board" is generally used to avoid confusion with the toxic substances known as polychlorinated biphenyls, also called PCBs. Some sources define the PWB as the board to which the electronics are attached, and refer to this entire component as the printed wired assembly (PWA). In this report, PWB refers to the board and the attached electronic components.

The average composition of a printed wiring board, by weight, is one-third ceramics and glass, one-third plastics, and one-third metals.[9] In addition to copper and gold (the most valuable components of a cell phone[10]), the PWB contains a variety of other precious metals and hazardous substances, including arsenic (in chips made from gallium arsenide), antimony, beryllium, brominated flame retardants, cadmium, lead (used in the solder that joins the parts), nickel, palladium, silver, tantalum, and zinc.

Printed wiring boards contained in all electronic products (not just cell phones) are the second largest source of lead in the US municipal waste stream. According to the Silicon Valley Toxics Coalition, all PWBs fail the toxicity characteristics leaching procedure (TCLP) test, which the US Environmental Protection Agency uses to determine whether a material should be classified as a hazardous waste.[11] Studies at Delft University of Technology have found that, of all the materials contained in a printed wiring board, the lead and brominated flame retardants have the greatest environmental impact (see chapter 3).[12]

Based on the Delft study, Figure 1.1 shows the breakdown of a handset's environmental impacts by component: 59 percent from the printed wiring board and 39 percent from the liquid-crystal display. The Delft study also found that 64 percent of a PWB's environmental impact comes from the integrated circuits, which thus account for 23 percent of the impact of the handset.

Figure 1.1 Environmental Impacts of Cell Phones



Source: Casper Boks *et al*., "Combining Economical and Environmental Considerations in Cellular Phone Design," *Proceedings of the 2000 IEEE International Symposium on Electronics and the Environment*.

The Liquid-Crystal Display

The liquid-crystal display is a crucial component of almost all electronic devices, displaying information to users. It contains liquid crystals embedded between layers of glass, back lighting for illumination, and transistors to provide an electric charge. The liquid crystalline substances used in LCDs are of many types and levels of toxicity. Lamps for large LCDs generally contain mercury, but manufacturers claim that the small LCDs used in cell phones do not.[13]

A study done by Philips Consumer Electronics and the Fraunhofer Institute in Berlin concluded that, because LCDs contain toxic substances, they should be separated at end of life from the electronic equipment that contains them; otherwise, the entire product should be treated as hazardous waste and stored in underground dumps, at a cost of approximately $3000 per ton. The study also concluded that foil display systems now under development would make LCDs much more "environmentally friendly," especially in small products.[14]

Germany's Federal Environmental Agency (UBA) reached a different conclusion after assessing the risks posed by LCDs based on tests done by manufacturers. It concluded that no special requirements are needed to manage the disposal of LCDs. According to UBA, a cell phone contains a very small quantity of liquid crystals — about 5 milligrams, compared to .3 to .4 gram in a notebook computer. The European Union's forthcoming directives for dealing with electronic equipment waste require the removal and special treatment of LCDs larger than 100 square centimeters. Most cell phone LCDs are much smaller than this and so would not be subject to the removal requirements.

In a study comparing the environmental impacts of LCDs and cathode-ray tubes in computers, the US EPA found some environmental advantages in the use of LCDs.[15] However, the LCDs studied were far larger than those used in cell phones and may contain different substances, so this analysis does not shed much light on the impacts of cell phone LCDs.

Changes in technology could render the issue moot. A new type of display is being developed by a number of companies (including Kodak, Sanyo, Philips, DuPont, and NEC) based on organic light-emitting diodes. This much-simpler display technology has the potential to be cheaper, more lightweight, and less power intensive than LCDs. Motorola has already introduced a cell phone — the Timeport P8767 — based on these diodes. Some technical problems remain to be solved, but organic light-emitting diodes could become the screen of choice in the cell phones of the future.[16] However, it is not yet clear what materials will be used and what their environmental impacts will be.

Other Cell Phone Components

A cell phone's power source — the batteries — can contribute substantially to its environmental impacts. These are discussed in detail in chapter 6.

The adapter used to charge the batteries may weigh more that the handset itself and is a major contributor to cell phone waste. Little analysis has been performed on the composition and environmental impacts of this component. Adapters consist mainly of copper wires encased in plastic, but materials such as gold, cadmium, and brominated flame retardants may also be present.

Most of the other components of the handset are very small: the speaker is about the size of a dime and the microphone is no larger than a watch battery. But these, too, contain heavy metals and hazardous materials. The case is made of plastics — usually polycarbonate (PC), acrylonitrile butadiene styrene (ABS), or a combination of the two. Recycling of these plastics is hampered by additives, particularly brominated flame retardants. Studies so far indicate that the environmental impacts of these components are dwarfed by those of the printed wiring board and liquid-crystal display.