Appendix C: Analysis I: Copper Recycling and Substitution

Is copper mining necessary? Some advocates, including Greenpeace, assert that copper recycling provides an alternative to seabed mining.[136] Copper prices are high, providing a strong incentive for recycling globally. Recycling currently provides a significant portion of the total annual copper supply. Though sources differ on the exact amount, it is likely above 30%. Increasing recycling is a goal that should be pursued globally. Copper is too valuable to be sent to a landfill. However, copper also has a long, useful life in most products. Mining today provides the vast majority of the copper supply. Demand for copper continues to rise, but is highly sensitive to economic downturns, particularly in the housing market. How best to mine copper with the fewest negative externalities or damaging impacts to communities, biodiversity, water quality, and natural systems is a critical question.

Mining seabed copper ore could displace terrestrial mining because the return per hectare of disturbance is high (disturbance is very low), saving communities, biodiversity, energy, and greenhouse gas emissions, and more. If increased copper recycling can be achieved, it should displace the most destructive copper ore mining. The following discussion examines recycling and the more potent option of substituting other technologies and materials for copper. The implications of recycling for the Solwara 1 proposal are also discussed.

Copper is virtually 100% recyclable; as an element, copper does not decay. Copper does not lose physical, chemical, or performance properties with recycling processes. Recycled copper is no different from copper smelted from ore. Recovering and recycling copper for reuse helps meet global demand, conserves natural resources, and improves sustainability by reducing environmental and social externalities. The process of recycling copper, called secondary production, uses far less energy—up to 85 % less—than primary production (mining). The current level of copper recycling saves an estimated 100 MW of electrical energy and 40 million metric tons of CO_2 each year.[137]

Recycled copper has remained a relatively stable portion of the growing copper supply, consistently supplying between 30% and 40% of the total copper supply since the 1950s. The demand for copper has increased dramatically from 2.5 million metric tons in 1950 to between 21 and 24 million metric tons in recent years, at an annual growth rate of 3.4%. This is despite dramatic copper price fluctuations, economic booms and busts, and some changes in copper applications. Of the estimated 24 million metric tons of copper used around the globe in 2010, 35% was sourced through recycling.[138] Part of the recent increase in the demand for copper comes from an increase in demand for end-of-life products such as laptops and cell phones, as well as the demand for plumbing and wiring with the growth in construction in developing countries.

Recycled copper can come from “old” scrap (end-of-life products found in electronics, households, cars, and industrial) and “new” scrap (factory scrap waste from the copper production process). Around 9 million metric tons of copper per year comes from both “old” and “new” scrap.[139]

A recent article in Environmental Sciences and Technology examined the total stock of copper in the global built capital economy. The article states: “Based on the global copper stocks and flows model, recently developed by the Fraunhofer Institute, it is estimated that two-thirds of the 550 million metric tons of copper produced, since 1900, are still in productive use.”[140] This approximately 360 million metric tons of copper is equivalent to a 17-year supply of copper at the current demand of 21 million metric tons per year. Yet, this copper is largely unavailable for recycling because it is still productively employed in buildings, equipment, generators, ships and other built capital assets.

Experts project that additional copper recycling will be necessary to keep up with the growing demand, but also expect that this will not relieve the full demand for copper from mining.[141] For recycling to effectively increase, there will need to be innovation in education. Cultural adoption must increase to raise recycling rates. Improvements in product design to facilitate recycling must proceed. Incentives motivating recovery must be implemented. Specific, proven catalyst programs will be required to achieve higher copper recycling rates, if copper recycling is to partially decrease the demand for mining sourced copper.[142]

Copper recycling has limitations. Fraunhofer and the International Copper Association have pointed out that there are copper losses during the smelting process, semi-finished production processes, with dissipation and abandonment of products, losses in scrap collection and losses in scrap separation processes. They do not estimate how much additional copper in the current global flow of copper could be additionally recycled. One of the difficulties of estimating copper availability for increased recycling is the lack of data concerning the amount of copper in the built capital stock that could be available for recycling, such as the copper contained in an obsolete generator in a farmer’s barn, versus the copper stock in built capital that is fully utilized, such as an operating generator in a farmer’s barn. Copper prices are high. The global recycling market is large, brisk and efficient. There is strong global awareness that recycling copper provides income. It appears that there is no easily available vast stock of copper simply waiting to be recycled.

Further research will be required to understand the full potential of copper recycling, but it is the opinion of Earth Economics that it is very unlikely to provide much more of the global copper supply than it currently provides within the next decade.

Overall, there is no question that mining is required to meet growing copper demand and to ensure that many people living in poverty can avail themselves of modern power, drinking water and electronic goods. Copper is generally applied in long-lived applications, such as house plumbing or generator windings. This is unlike an aluminum beverage can, which has a short life between recycling events. Copper applications have useful lifespans that can easily last decades as in power station generators. In addition, much of the copper consumption provides new services such as rural electrification, residential construction, and industrial applications, particularly in China and India. Thus, according to the International Copper Study Group (ICSG), "recycled copper alone cannot meet society's needs."[143] The only opportunity for greatly increasing copper recycling would be to displace copper currently in use with substitute materials.

For many applications, copper is a difficult material to replace because it performs so well as a power and heat conductor. Copper has been a necessity for applications in domestic and industrial infrastructure and high technology for decades, and will continue to be essential to both developed and developing nations. There has, however, been growing research and development in alternative materials and substitutes for copper. Carbon-based conductor replacement materials are on the technological horizon.[144]

Carbon-based conductor replacement materials are being researched for applications in aerospace, oil platforms, and optoelectronic devices. Carbon nanotube conductor cables, currently under development, show promise. They have been shown to carry four times as much current as copper wire of the same mass, but at a fraction of the weight.[145] Overall, however, there is currently no satisfactory substitute for copper commercially available for many applications. If price-competitive carbon-based nanocomposite products can be produced at a large enough scale, then the demand for copper in power distribution cabling could be reduced. According to a report by BCC Research, "Global consumption of nanocomposites is expected to grow in unit terms from nearly 225,060 metric tons in 2014—an estimated value of over $1.2 billion—to nearly 584,984 metric tons in 2019— $4.2 billion in value—at a compound annual growth rate (CAGR) of 21.1 % for the period of 2014 to 2019."[146] This growth represents the application of nanocomposites to far more than copper replacement applications.

Copper recycling rates could be increased if many products were redesigned to facilitate cost-effective copper recovery (and the recycling of other materials). This is happening more rapidly in some industries, such as computer manufacturing. It is important to keep scale in mind. Cell phones have a relatively short lifespan for copper applications, and they are not designed for easy mineral recovery. In addition, a vast increase in recycling of cell phones would not move the world market in copper. For one million cell phones gone to waste, 1.6 metric tons of copper has also gone to waste, however.[147] This is a relatively insignificant amount of copper. Few cell phones are going to waste. Every phone is worth recycling, not only for the copper, but also for the gold, cobalt, niobium and more. The entire global stock of roughly 4 billion cell phones contains about 6,400 metric tons of copper. This amount would be dwarfed by the stock of copper plumbing currently in buildings if it were recycled, yet most copper plumbing is still in use. Copper plumbing is difficult to replace, and the cost of replacement far exceeds the income that would be generated by copper recycling.

Existing residential and commercial building communications wiring throughout the developed world could be viewed as a vast 'copper mine'. In the case of telecommunications, substitutes with less cost and greater productivity exist. Pulling wires from buildings is far less costly than pulling plumbing. Most voice and data communications can now be conducted over fiber optic networks or wireless systems. While telecommunications used to be the largest market for copper in the U.S. forty years ago, the use of copper in telecommunications cables has since declined sharply with the rise of fiber optic and wireless technology.[148] Fiber links are proven to be a more efficient application for communications, providing over 1,000 times as much bandwidth and 100 times the distance capability, not to mention the capacity to handle more information at a faster rate and with a clearer signal.[149] If the US government were to upgrade its inventory of 436,000 buildings with wireless & fiber networks and reclaim the now obsolete copper wiring, thousands of metric tons, but not millions of metric tons, of copper could be recycled.

Counterbalancing substitution away from copper is the phase out of other metals or materials, such as lead solder, where copper may be part of the replacement for more toxic or lower performance materials. Increased use of copper is the solution in some applications, particularly copper in alloys that are less toxic, more conductive, or more durable substitutes.

There is also growing demand for copper in renewable energy. Over the last decade, increasing investment of renewable resource energy infrastructure and technologies in the U.S. has increased four-fold, from $10.4 billion in 2004 to over $44.2 billion.[150] To increase renewable energies, wind, wave, geothermal, tidal and photovoltaic (PV) solar power systems all use copper in their wiring, tubing, cables, and generators (PV has no generators). Offshore wind energy systems use up to 9.5 metric tons of copper per MW of power. Land-based wind energy systems use

2.5 to 7 metric tons of copper per MW, and PV solar panels use over 2 metric tons of copper per MW of power produced.[151] Copper demand for this sector is increasing sharply. [Offshore wind power photo]

President Obama's 2013 Climate Action Plan committed to double US wind and solar generation by 2020. This alone could increase the usage of copper between 80,000 and 140,000 metric tons. China has far more ambitious plans for expanding wind power as well as coal, gas and nuclear power plants, which all require vast amounts of copper. When it comes to renewable energy systems, copper is a preferred material. It is reliable, efficient and long lived, with high performance qualities.[152]

The global demand for copper is dominated by Asia and China in particular. China consumes 40 % of the world's annual copper production. Demand in Asia has expanded fivefold over the last 30 years, to about 13,739 million metric tons in 2013. More than half the total global copper consumption was in Asia in 2013.[153] For copper recycling to have a significant impact in reducing the demand for mining, there would need to be a large transfer of copper stock from North America, Europe and Japan to China. Because China is expanding copper use in residential and industrial sectors, power distribution, generators, renewable energy and other areas, China has little historic copper stock to tap for recycling.

Globally, and very broadly, the end use of copper has the following sector breakdown: 30% building construction, 30% equipment, 15% infrastructure, 13% transport, and 12 % industrial. Construction accounts for 55% of copper consumption in China. Domestic non-construction consumption accounts for 29% of copper consumption in China. Exports account for 16% of China's copper consumption.[154]

Displacing built infrastructure copper uses with substitutes and pulling copper from existing in-use buildings could open up a significant supply of copper for recycling. Substitutes exist, for example, copper plumbing could be replaced by Pex plumbing systems. Copper wiring could be replaced by aluminum wiring. Copper-based communications wiring could be replaced by fiber optic and wireless. However, these scenarios are not yet economical for much of the copper stock in place. When a wireless system is put into an existing house, the redundant copper wiring is left in place.

Some of these substitutes have significant environmental impacts as well, and may not result in a net gain for sustainability. For example, aluminum replacement of copper wiring requires bauxite mining and is far more energy-intensive in the smelting process. Aluminum has replaced copper in aircraft and some transmission applications, but is not expected to replace the bulk of copper wiring. In addition, aluminum has a larger heat expansion coefficient and has been tied to an increased rate of house fires over copper wiring. Pex plumbing systems are based on high quality plastic pipes with copper fittings. Pex is currently more expensive than copper plumbing. Pex also requires crude oil, refining, plastics and chemical production with the attendant environmental and social impacts. Optic fiber has a far superior performance over copper for communications uses. This technological advantage and market forces have driven the replacement of copper by optic fiber. Despite this significant substitution, global demand for copper has expanded.

Finally, new systems designs that could more closely twin previously segmented parts of the economy might reduce copper consumption. For example, the twinning of renewable power such as windmills with smaller distributed data centers located at the windmill sites could cut copper use as this pairing would integrate the power grid with communications and internet systems, using more robust fiber optic networks. In this case, there would be a shift from moving electrons to moving photons. Instead of moving 24 MW of power from a power plant to a large data center (currently the power demand for a large-scale four hectare data center), which involves large power losses, a distributed data center system would locate appropriately sized data centers at the power sources. Data centers already have substantial battery capacity, 24 MW for two minutes at a four-hectare data center, with additional diesel generating capacity that stands idle awaiting a possible power outage. In this case, the data center batteries could also be used to store wind power for sale in peak periods as part of the power grid. With a power consumer at the windmill site, power efficiency increases greatly as do the economics for the windmill owner. The micro data centers could purchase off-peak power, as well as store and sell power at peak loads. The network of micro data centers could be managed just as a large 10-hectare data center is managed today, optimizing use across the processor pool. In this case, unlike a traditional data center, battery usage could also be optimized. This would facilitate moving photons down fiber optic cables rather than electrons down power cables. The substitution would reduce the need for copper in transmission lines and cabling in data centers. However, there is an enormous stock of large data centers globally, and no rapid transition to a radically integrated power and communications network is currently underway.

Overall, copper recycling is at a high global rate. Copper stocks in built capital assets, such as buildings and generators, are in use. Recycling cannot be dramatically increased in the short-term. The stock of copper in the world's built capital is colossal. The need for an increased stock of copper in performing built capital such as residential houses, renewable power and electronics is growing, and must continue to grow if much of the world's population is to escape abject poverty.

Substitution and the urban mining of this copper stock for recycling in the future could provide a significant and less costly source for the copper supply. However, this transition would be disruptive, such as pulling copper piping from existing buildings to replace with Pex, and is neither economically viable today, nor is it on the near horizon.

Even if there were the ability to mine large built capital copper stocks, two questions would remain. First, with the level of copper mining yet required, though it may be a lower level, where could that copper best be mined with the least natural capital and social impacts? This study supports the projection that seabed copper mining will likely dramatically outperform terrestrial copper mining (open-pit or below ground). Second, are large-scale substitutes such as aluminum wiring, Pex plumbing, or fiber optic actually more sustainable than copper? Optic fiber is unquestionably a superior substitution for copper and markets have powered this substitution. Other substitutes remain more costly, with less performance value, and may not be more sustainable than copper.

There is potential for increased copper recycling. Significantly increasing copper recycling could have two paths. First, redesigning products so that more copper can be pulled from these products when their useful life is complete. Second, the only route to significantly large-scale recycling would be the substitution of other materials and technologies for a significant portion of the copper stock currently in use. This would require a system for replacing the services of copper and cheaply mining built capital copper stocks without damaging in-use buildings and other facilities.

Though this may be viable in the future, it is not here today. In addition, studies on the environmental and social impacts of substitutes would need to be conducted.

There are important conclusions.

1. Copper recycling and the substitution of other materials and technologies for the current in-use copper stock will not be realized in the near future (the next two decades), thus, demand for copper ore will remain high and copper mining will likely expand globally.

2. Even if mining a significant portion of the estimated 360,000 million metric tons of copper serving the current global built capital stock became feasible, copper ore mining would still be required to meet global demand, and seabed mining appears to be an option that could outperform terrestrial copper mining with far less environmental and social impacts, garnering far higher ore concentrations.