The electrical storage movement and the global demand for graphite.

Why is Tesla targeting non-mobile storage systems? As an order-of-magnitude estimate, with full integration of worldwide renewable energy sources and maintaining a constant flow through the grid, up 2,8000 GW of electrical storage capacity (production and consumer) may be required worldwide.

There are currently three alternatives for the storage of electricity; lithium ion and vanadium reduction batteries, and fuel cells. All three use about four tonnes of graphite per MWhr. Assuming a slight grown in demand by the time the system is fully installed an initial total of 12 million tonnes of graphite plus an additional 1.2 million tonnes on a yearly basis (20 year lifespan and 5% annual increase in grid capacity) could be required.

To answer the Tesla question you have to know the current state of the electrical grid and alternatives to the increasing outdated, and overworked system. The present electrical grid infrastructure is decades old and is approaching 100% capacity during peak load hours; particularly on hot summer days. In a simplified form the grid consists of three components: generators, transmission and consumers.

However, there is often significant excess capacity at non-peak hours. Rather than expanding the current grid and replacing aging infrastructure, the availability of large scale electricity storage systems gives another alternative; that is a distribution system wherein significant power is stored at a consumer level and the even integration of renewables into the system. In the past physical means of storage have been advocated including pumping water into hydroelectric reservoirs and compressing air in underground caverns. None of these systems have proved to be viable. Thus the stationary battery or its alternatives.

Installed storage capacity would create a system that is more resilient to power failure allowing both consumption and production to continue when the grid is not available. With the exception extraordinarily long events, such as major storms, power disruptions would be a thing of the past. The storage system would also allow built in surge protection and very close regulation of the quality of the electricity both into and out of the grid. Such a system would also allow many parts of the grid to convert to high voltage direct current allowing existing transmission wires to carry up to 40% more power.

Generators consist of slow responding, but inexpensive base-load capacity, some more responsive generators for “shoulder periods” and quick acting peak generators. The base-load generators are always on-line and produce the even supply dictated by the demand minimum. Electricity on the grid must be balanced. Thus, as demand increases the faster responding generators are brought online or run at a higher capacity. Some generator power is not used, but is dissipated and can be brought on-line immediately in the case of surges. Without storage, what goes into the grid must come out. Renewable energy sources such as wind, solar, and tidal energy cannot be controlled thus can only make up a small percentage of the grid or instabilities result. This means that there are limits to the quantity of renewables that can be safely integrated.

Consider the case of solar power. Electricity is only generated during the day, peaking at about noon. The peak occurs during “shoulder”, or mid load thus would allow some of the moderately responsive generators to idle; but, solar cannot replace them as the power is required during evening hours. Also, the amount of generated power cannot exceed what those generators would normally provide as base-load generators cannot be idled in the same manner. Thus solar usage under the current system is limited. However, by adding storage to the system the solar generator could supply any capacity, to its maximum, upon demand. The amount generated depends on the weather, the latitude and the hours of sunlight which means that a storage safety factor will have to be included.

Solar is predictable, with minor variations. Tidal power is entirely predictable thus the easiest to compensate. Wind, on the other hand, is much more variable unless the turbine is located in a very favorable zone. Due to calm days and high velocity wind during storms there can be a considerable variation as captured by the wind generation in Germany during one month in 2009 as shown in Figure 2. A daily storage would not suffice for wind, rather, wind patterns over time would need to be analyzed to determine a monthly or even longer compensation storage system.

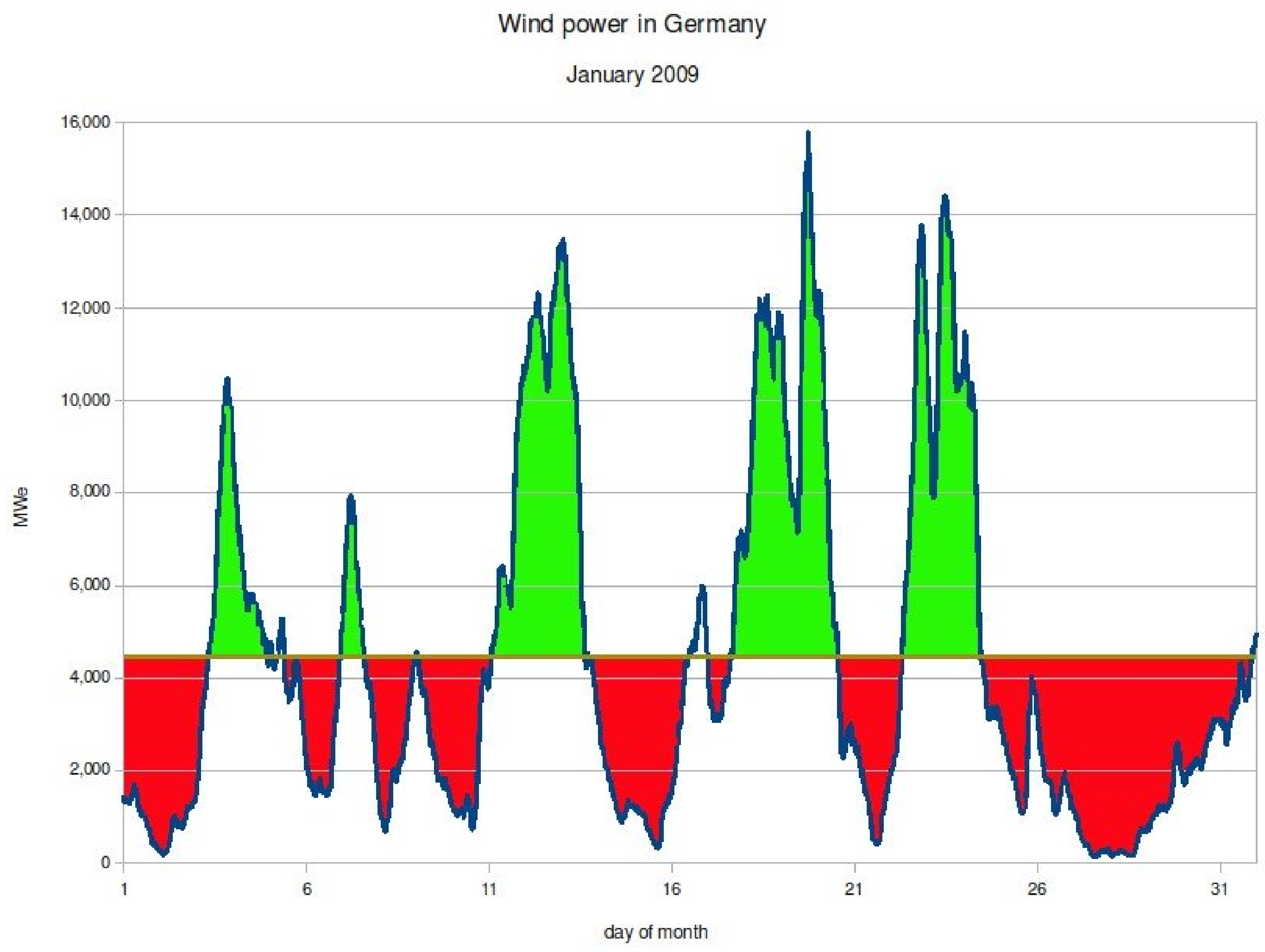

Figure 1: German wind generated power from January 2009. Red shows power output from storage systems that along with the power stored (green) would result in a constant power output.

As there are periods wherein there is no power generated the system must be capable of storing all power from the base-load output to the peaks and outputting all the power for that load from the batteries. The amount of electricity stored would be the maximum anticipated power as represented by the area of the largest red section (time and MW for MWhrs).

What is the total power that must be stored in order to maximize grid performance and totally integrate renewables into the system? As a very rough approximation, the total power generated in the world is on the order of terawatts, or thousands of gigawatts. Assuming a value of 4,000 GW and a further assumption that 30% of the power would have to be stored to create an even flow, there must be 1,200 GW storage ability worldwide.

The scenarios shown illustrate the even grid flow of electricity that can used to maximize the carry capacity of the grid. However, to allow this state of operation the consumer side also has to be buffered with electrical storage. Residential, commercial and industrial users of electricity do not have even demand during the day. Illustrations of these demand are shown in Figure 2 through Figure 4.

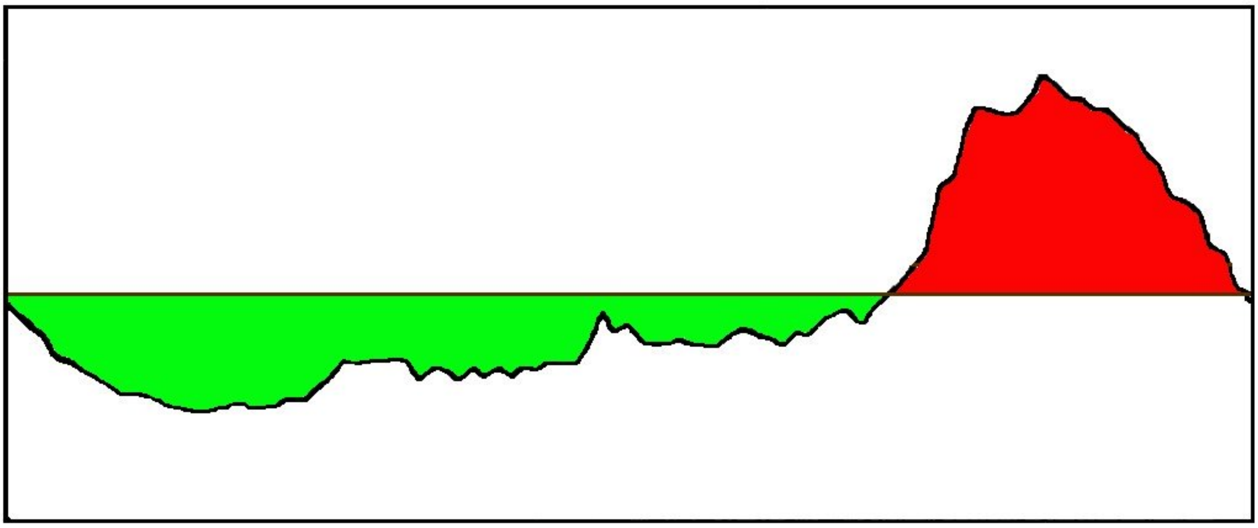

Figure 2: Typical residential daily electrical consumption over a 24 hour period. Green shows local battery storing power and red indicates battery output of power in order to create an even consumption of power with time.

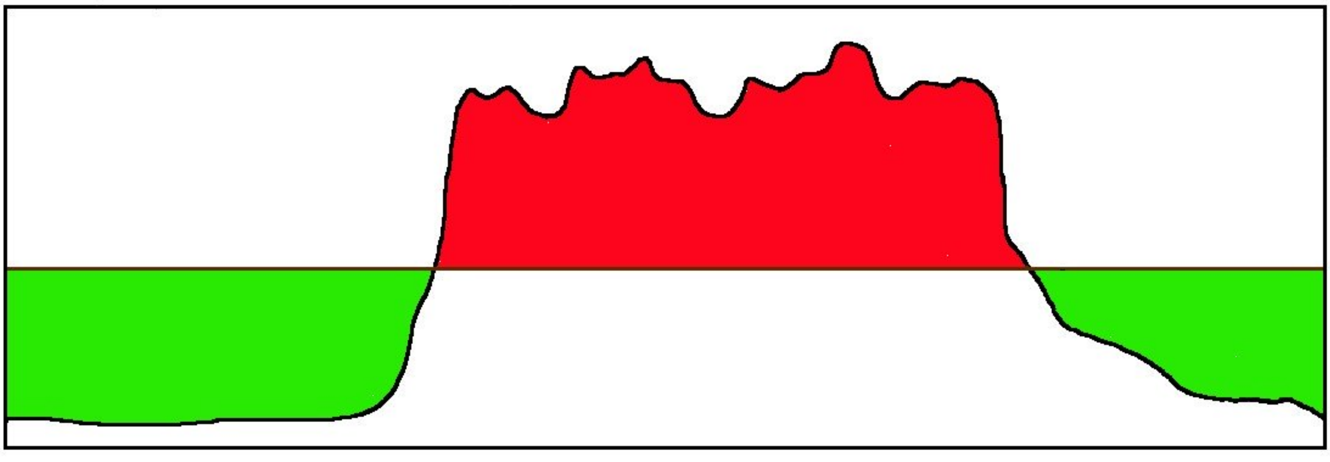

Figure 3: Typical commercial daily electrical consumption over a 24 hour period. Green shows local battery storing power and red indicates battery output of power in order to create an even consumption of power with time.

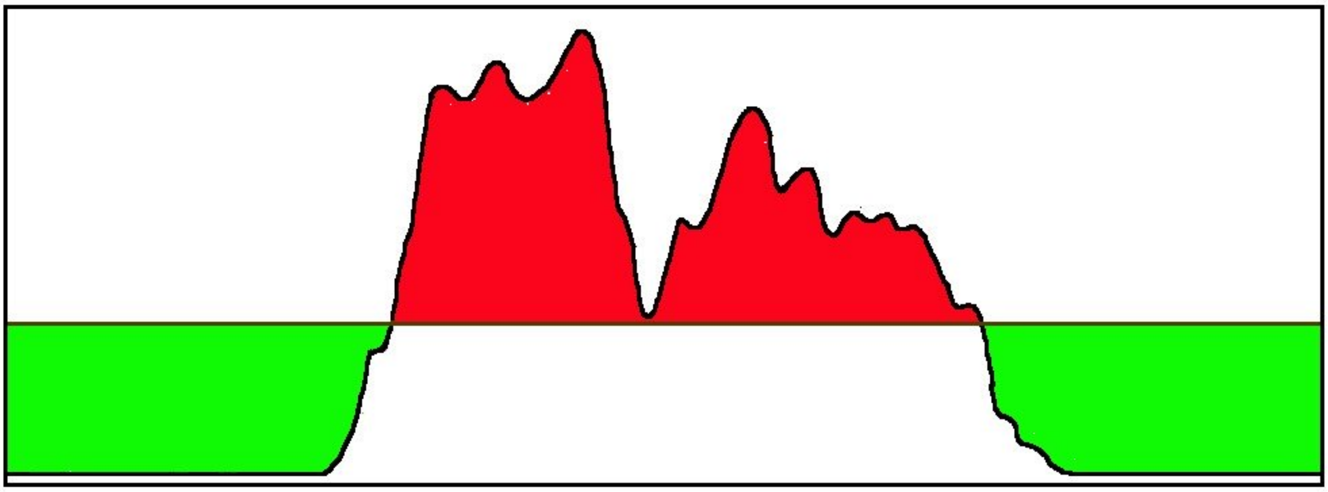

Figure 4: Typical small industrial daily electrical consumption over a 24 hour period. Green shows local battery storing power and red indicates battery output of power in order to create an even consumption of power with time.

In all three electrical consumer scenarios the battery storage system required to create an equal demand with time is the area of either the red or green zones (both are equal). As both commercial and small scale industrial operate only during daylight hours they would require a larger storage system, compared to their total consumption then residence that always has a load. If it is assumed that this is half of the power, it means that, worldwide, consumer storage will be fairly similar to renewable generator storage. As an added benefit such a storage system would mean that generate or wider distribution grid failures could be compensated for at the local level for periods of up to half a day.

How much electricity would be stored at the consumption end of the grid? As an order-of-magnitude, this would be about 50% for both commercial and industrial and about 30% for residential resulting in a very approximate total of about 40%

or 1,600 GW worldwide.