//Front Cover

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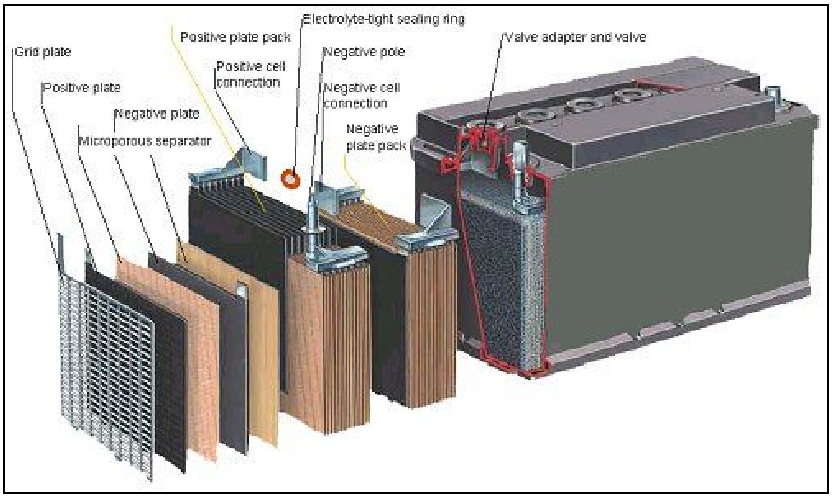
I will be researching **secondary cells** which are **rechargeable** and can be used to power a house, primary cells will not be suitable as they are non-rechargeable.

2.a. Lead Acid - The oldest type of rechargeable battery invented in 1859 by french physicist Gaston Plante. It has a low energy-to-weight ratio and a low energy-to-volume ratio but because it's able to supply high surge currents means that it has a high power-to-weight ratio. They are commonly used in motor vehicles because they provide a high current for the starter motor, large format lead-acid designs are used as a backup power supply in cell phone towers, hospitals and stand-alone power systems. At the moment are inexpensive compared to newer technologies like lithium-ion and lithium polymer. In 1999 45% of battery sales worldwide were from lead acid and gave the manufacturing market a value of $15Billion.



The **lead-acid battery** was invented in 1859 by French physicist Gaston Planté and is the oldest type of rechargeable battery. Despite having a very low energy-to-weight ratio and a low energy-to-volume ratio, its ability to supply high surge currents means that the cells have a relatively large power-to-weight ratio. These features, along with their low cost, makes it attractive for use in motor vehicles to provide the high current required by automobile starter motors.
As they are inexpensive compared to newer technologies, lead-acid batteries are widely used even when surge current is not important and other designs could provide higher energy densities. Large-format lead-acid designs are widely used for storage in backup power supplies in cell phone towers, high-availability settings like hospitals, and stand-alone power systems. For these roles, modified versions of the standard cell may be used to improve storage times and reduce maintenance requirements. *Gel-cells* and *absorbed glass-mat* batteries are common in these roles, collectively known as VRLA (valve-regulated lead-acid) batteries.
In 1999 lead–acid battery sales accounted for 40–45% of the value from batteries sold worldwide excluding China and Russia, and a manufacturing market value of about $15 billion.[8]

https://en.wikipedia.org/wiki/Lead%E2%80%93acid_battery

2.b. Nickel Metal Hydride (NiMH) - A type of rechargeable battery which uses nickel oxide hydroxide(NiOOH) at the positive electrode, the negative electrodes use a hydrogen absorbing alloy instead of cadmium, it can have up to 3 times the capacity of a Nickel Cadmium (NiCd) battery and can nearly have an energy density of a lithium-ion battery.

https://3.imimg.com/data3/OQ/VK/MY-15577467/nimh-battery-500x500.jpg

A **nickel–metal hydride battery**, abbreviated **NiMH** or **Ni–MH**, is a type of rechargeable battery. The chemical reaction at the positive electrode is similar to that of the nickel–cadmium cell (NiCd), with both using nickel oxide hydroxide (NiOOH). However, the negative electrodes use a hydrogen-absorbing alloy instead of cadmium. A NiMH battery can have two to three times the capacity of an equivalent size NiCd, and its energy density can approach that of a lithium-ion battery.

https://en.wikipedia.org/wiki/Nickel%E2%80%93metal_hydride_battery

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Specific energy:	60–120 Wh/kg
Energy density:	140–300 Wh/L
Specific power:	250–1,000 W/kg
Charge/discharge efficiency:	66%[1]–92%[2]
Self-discharge rate:	13.9–70.6% at room temperature: 36.4–97.8% at 45 °C
Low self-discharge:	1.3–2.9% at 20 °C (per month)
Cycle durability:	180[3]–2000[4] cycles
Nominal cell voltage:	1.2 V

2.c. Nickel Cadmium (NiCd) - Similar to the NiMh battery as it uses nickel oxide hydroxide as a for the positive electrode, except it uses metallic cadmium for the negative electrode. Wet cell NiCd batteries were invented in 1899 losing market share of 80% in the 90's due to NiMh and Li-Ion batteries, has a voltage of 1.2V on discharge descreasing little until the end of discharge. They are made in a wide range of sizes and capacities. Offer a good life cycle and performance at low temperatures with a moderate capacity. The main advantage of these are that they can deliver their full rated capacity at high discharge rates. They are more expensive than the lead-acid batteries. NiMh replaced these because NiCd has a lower capacity and are more expensive to manufacture, they are also more toxic to the environment when disposed.

http://www.batteryspace.com/images/products/detail/179.2.png

The **nickel–cadmium battery** (**NiCd battery** or **NiCad battery**) is a type of rechargeable battery using nickel oxide hydroxide and metallic cadmium as electrodes. The abbreviation *NiCd* is derived from the chemical symbols of nickel (Ni) and cadmium (Cd): the abbreviation *NiCad* is a registered trademark of SAFT Corporation, although this brand name is commonly used to describe all Ni–Cd batteries.

Wet-cell nickel-cadmium batteries were invented in 1899. Among rechargeable battery technologies, NiCd rapidly lost market share in the 1990s, to NiMH and Li-ion batteries; market share dropped by 80%.[citation needed] A NiCd battery has a terminal voltage during discharge of around 1.2 volts which decreases little until nearly the end of discharge. NiCd batteries are made in a wide range of sizes and capacities, from portable sealed types interchangeable with carbon-zinc dry cells, to large ventilated cells used for standby power and motive power. Compared with other types of rechargeable cells they offer good cycle life and performance at low temperatures with a fair capacity but their significant advantage is the ability to deliver practically their full rated capacity at high discharge rates (discharging in one hour or less). However, the materials are more costly than that of the lead acid battery, and the cells have high self-discharge rates.

Sealed NiCd cells were at one time widely used in portable power tools, photography equipment, flashlights, emergency lighting, hobby R/C, and portable electronic devices. The superior capacity of the Nickel-metal hydride batteries, and more recently their lower cost, has largely supplanted their use. Further, the environmental impact of the disposal of the toxic metal cadmium has contributed considerably to the reduction in their use. Within the European Union, NiCd batteries can now only be supplied for replacement purposes or for certain types of new equipment such as medical devices.[2]

Larger ventilated wet cell NiCd batteries are used in emergency lighting, standby power, and uninterruptible power supplies and other applications.

https://en.wikipedia.org/wiki/Nickel%E2%80%93cadmium_battery

Specific energy: 40–60 W·h/kg
Energy density: 50–150 W·h/L
Specific power: 150 W/kg
Charge/discharge efficiency: 70–90%[1]
Self-discharge rate 10%/month
Cycle durability 2,000 cycles
Nominal cell voltage 1.2 V

2.d. Lithium Ion - The most common type of battery used in electronics, they have a high energy density, tiny memory effect and low self discharge. Are becoming more popular in army, electric powered cars and aerospace. They are replacing lead-acid batteries as the lithium ion batteries are lighter than lead plates, they can also provide the same voltage as the former lead-acid batteries. The first lithium-ion battery was developed in 1991 by sony.

https://images-na.ssl-images-amazon.com/images/I/41u7Hh78sLL._SX425_.jpg

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Specific energy density: 100 to 250 W·h/kg (360 to 900 kJ/kg)[97]
Volumetric energy density: 250 to 620 W·h/L (900 to 2230 J/cm³)[2]
Specific power density: 300 to 1500 W/kg (at 20 seconds and 285 W·h/L)

Because lithium-ion batteries can have a variety of positive and negative electrode materials, the energy density and voltage vary accordingly. The open circuit voltage is higher than aqueous batteries (such as lead acid, nickel-metal hydride and nickel-cadmium).[98] Internal resistance increases with both cycling and age.[98][99] Rising internal resistance causes the voltage at the terminals to drop under load, which reduces the maximum current draw. Eventually increasing resistance means that the battery can no longer operate for an adequate period. Batteries with a lithium iron phosphate positive and graphite negative electrodes have a nominal open-circuit voltage of 3.2 V and a typical charging voltage of 3.6 V. Lithium nickel manganese cobalt (NMC) oxide positives with graphite negatives have a 3.7 V nominal voltage with a 4.2 V maximum while charging. The charging procedure is performed at constant voltage with current-limiting circuitry (i.e., charging with constant current until a voltage of 4.2 V is reached in the cell and continuing with a constant voltage applied until the current drops close to zero). Typically, the charge is terminated at 3% of the initial charge current. In the past, lithium-ion batteries could not be fast-charged and needed at least two hours to fully charge. Current-generation cells can be fully charged in 45 minutes or less. In 2015 researchers demonstrated a small 600 mAh capacity battery charged to 68 percent capacity in two minutes and a 3,000 mAh battery charged to 48 percent capacity in five minutes. The latter battery has an energy density of 620 Wh/L. The device employed heteroatoms bonded to graphite molecules in the anode.[100] Performance of manufactured batteries has improved over time. For example, from 1991 to 2005 the energy capacity per price of lithium ion batteries improved more than ten-fold, from 0.3Wh per dollar to over 3Wh per dollar.[101]

Uses

Li-ion batteries provide lightweight, high energy density power sources for a variety of devices. To power larger devices, such as electric cars, connecting many small batteries in a parallel circuit is more effective[126] and more efficient than connecting a single large battery.[127] Such devices include:

- *Portable devices*: these include mobile phones and smartphones, laptops and tablets, digital cameras and camcorders, electronic cigarettes, handheld game consoles and torches (flashlights).
- *Power tools*: Li-ion batteries are used in tools such as cordless drills, sanders, saws and a variety of garden equipment including whipper-snippers and hedge trimmers.
- *Electric vehicles*: Because of their light weight Li-ion batteries are used for propelling a wide range of electric vehicles and hybrid vehicles, such as aircraft,[128][129][130] electric cars,[131] Pedelecs, advanced electric wheelchairs, radio-controlled models, model aircraft and the Mars *Curiosity* rover.

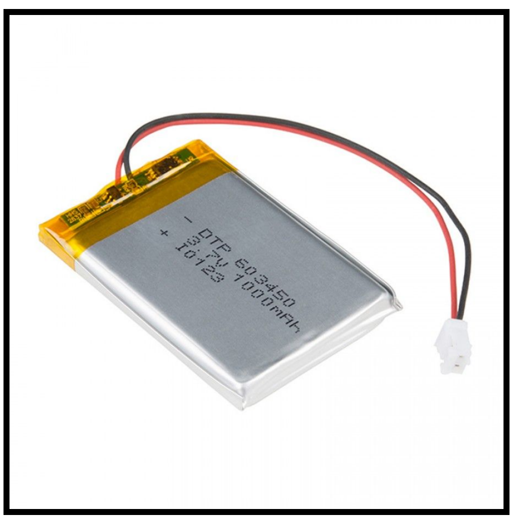
Li-ion batteries are used in telecommunications applications. Secondary non-aqueous lithium batteries provide reliable backup power to load equipment located in a network environment of a typical telecommunications service provider. Li-ion batteries compliant with specific technical criteria are recommended for deployment in the Outside Plant (OSP) at locations such as Controlled Environmental Vaults (CEVs), Electronic Equipment Enclosures (EEEs), and huts, and in uncontrolled structures such as cabinets. In such applications, li-ion battery users require detailed, battery-specific hazardous material information, plus appropriate fire-fighting procedures, to meet regulatory requirements and to protect employees and surrounding equipment.[132

Battery life

Rechargeable battery life is typically defined as the number of full charge-discharge cycles before significant capacity loss. Inactive storage may also reduce capacity.
Manufacturers' information typically specify lifespan in terms of the number of cycles (e.g., capacity dropping linearly to 80% over 500 cycles), with no mention of chronological age.[138] On average, lifetimes consist of 1000 cycles,[139] although battery performance is rarely specified for more than 500 cycles. This means that batteries of mobile phones, or other hand-held devices in daily use, are not expected to last longer than three years. Some batteries based on carbon anodes offer more than 10,000 cycles.[140]
As a battery discharges, its voltage gradually diminishes. When depleted below the protection circuit's low-voltage threshold (2.4 to 2.9 V/cell, depending on chemistry) the circuit disconnects and stops discharging until recharged. As discharge progresses, metallic cell contents plate onto its internal structure, creating an unwanted discharge path.[citation needed]
Defining battery life via full discharge cycles, is the industry standard, but may be biased, since full depth of discharge (DoD)/recharge may itself diminish battery life, compared to cumulative Ah partial discharge/charge performance. Projection from the standard to specific use patterns may require additional factors, e.g. DoD, rate of discharge, temperature, etc.

As Lithium-Ion technology appears to be the best option for high power, low weight, low volume battery, I will document the types of Lithium Ion technology:

2.e. Li-polymer - Uses lithium ion technology except it has a polymer electrolyte instead of a liquid electrolyte, it has high conductivity semisolid polymers form the electrolyte for LiPo. Commonly used in tablet computers and many cellphones. Lipo cells have a flexible, foil-type case, so they are relatively unconstrained, they are 20% lighter than the equivalent cylindrical cells found in lithium-ion technology. It can be made in next to any shape.



http://www.robotshop.com/media/catalog/product/cache/1/image/900x900/9df78eab33525d08d6e5fb8d27136e95/l/i/lithium-polymer-battery-cell-37v-1000mah.jpg

https://en.wikipedia.org/wiki/Lithium_polymer_battery

Specific energy 100–265 W·h/kg(0.36–0.95 MJ/kg)
Energy density 250–730 W·h/L(0.90–2.63 MJ/L)

2.f. Lithium cobalt oxide (High Energy Density but safety risks when damaged)

2.g. **Lithium iron phosphate**

http://www.evwest.com/catalog/images/thumbs/def/large/products/voltronix-60-ah-lithium-iron-phosphate-battery.jpg?osCsid=qcu5pemkdsmf6vnngnfcg8scp6

(Low Energy Density but longer life and safer)

Specific energy 90–110 Wh/kg (320–400 J/g or kJ/kg)
Energy density 220 Wh/L (790 kJ/L)
Specific power around 200 W/kg[1]
Energy/consumer-price 3.0–24 Wh/US$[2]
Time durability > 10 years
Cycle durability 2,000 cycles
Nominal cell voltage 3.2 V

2.h. Lithium ion manganese oxide

2.i. Lithium nickel manganese cobalt oxide

2.j. Lithium nickel cobalt aluminum oxide

https://sc02.alicdn.com/kf/HTB1cP0DNpXXXXaQXpXXq6xXFXXXF/lithium-nickel-manganese-cobalt-oxide-battery-72v.jpg

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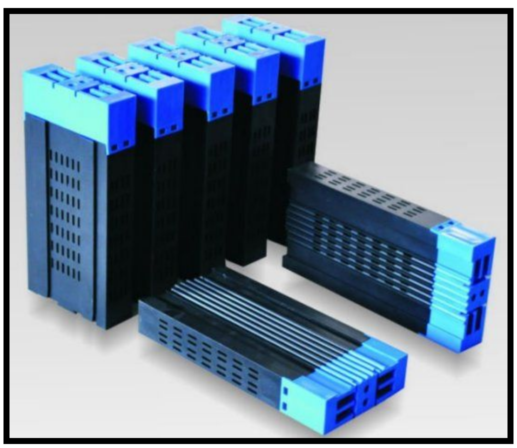
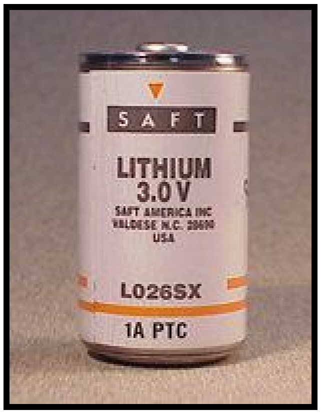
2.k.Lithium titanate (are specialty designs aimed at particular niche roles)



The **lithium–titanate battery** is a type of rechargeable battery, which has the advantage of being faster to charge than other lithium-ion batteries. Titanate batteries are used in certain Japanese-only versions of Mitsubishi's i-MiEV[1] electric vehicle and Honda uses them in its EV-neo electric bike and Fit EV.[2][3] Opportunity charging in public transportation, such as large capacity electric bus project TOSA, is using the Titanate batteries high charging capability to partly recharge the battery in 15 seconds while passengers are disembarking and embarking at bus stops[4]
A lithium–titanate battery is a modified lithium-ion battery that uses lithium-titanate nanocrystals on the surface of its anode instead of carbon. This gives the anode a surface area of about 100 square meters per gram, compared with 3 square meters per gram for carbon, allowing electrons to enter and leave the anode quickly. This makes fast recharging possible and provides high currents when needed.[5]
A disadvantage of lithium-titanate batteries is that they have a lower inherent voltage (2.4 V), which leads to a lower specific energy of about 30-110Wh/kg[6] than conventional lithium-ion battery technologies (which have an inherent voltage of 3.7 V).[7]
Lithium-titanate batteries are reported to have an energy density of up to 177 Wh/L.[6]

2.Lithium–sulfur (highest performance-to-weight ratio)



http://www.hdssystems.com/Products/Legacy/LiSO2D/LithiumDSo2Battery.jpg

Specific energy 500 W·h/kg demonstrated
Energy density 350 W·h/L
Charge/discharge efficiency C/5 nominal
Cycle durability disputed
Nominal cell voltage cell voltage varies nonlinearly in the range 2.5–1.7 V during discharge; batteries often packaged for 3V

3. Battery Cell Technology Comparison
Table a - General Overview
Table b - Lithium Batteries
Table c -

Table a - A brief overview of the technologies/cell type we can use…

Cell chemistry	Rechargeable	Energy density by mass	Energy density by volume	Specific power	Cost†
		W/kg	Wh/$ ($/kWh)	%	%/month
Lead-acid	Yes	30–40	60–75	180[2]	3–20
Alkaline	No	85-190	250-434	50[12]	0.17
Nickel-cadmium	Yes	30	100	150-200[28]	10
Nickel-metal hydride	Yes	100	401	250-1000	30
Lithium-iron disulfide	No	297	580		0.05
Lithium cobalt oxide	Yes	195	560		
Lithium iron phosphate	Yes	90-130	333	200 [49]	4.5
Lithium manganese oxide	Yes	150	420		
Lithium nickel cobalt aluminum oxide	Yes	220	600		
Lithium nickel manganese cobalt oxide	Yes	205	580		

Table b (Lithium ion) - As lithium ion technology seems the most promising I will further research types of this technology, there are many types of lithium ion technology as shown and compared below.

Tech	By mass	By volume	Specific Power	Cost	Year
Lithium Ion	100-265Wh/Kg	250-690Wh/L	250-340W/Kg	2.5Wh/$	
Lithium-Titanate	30-100Wh/Kg	177Wh/L			
Lithium-Sulfur	500Wh/Kg	350Wh/L			
Lithium-iron disulfide	297Wh/Kg	580Wh/L	1.07W/Kg	0.05	1989
Lithium cobalt oxide	195Wh/Kg	560Wh/L	0.70W/Kg		1991
Lithium iron phosphate	90-130Wh/Kg	333Wh/L	0.32–0.47W/Kg		1996
Lithium manganese oxide	150Wh/Kg	420Wh/L	0.54W/Kg		1999
Lithium nickel cobalt aluminum oxide	220Wh/Kg	600Wh/L	0.79W/Kg		1999
Lithium nickel manganese cobalt oxide	205Wh/Kg	580Wh/L	0.74W/Kg		2008
Lithium-carbon monofluoride	260–780Wh/Kg	440–1,478Wh/L	50–80W/Kg		1976

Considering the oldest battery cell technology is lead acid and the latest we have today is lithium ion, I will create multiple tables and graphs showing costs, energy capabilities, weight, size and how these features have improved over time then use this to predict how much this will advance in the future.

4.a. Manufacture Costs

//Insert table here

//Insert chart here

www.mdpi.com/2313-0105/3/2/17/pdf

X axis (Year)
Y axis (manufacture costs)

Manufacturing costs of batteries for electric vehicles **-**
https://books.google.co.uk/books?hl=en&lr=&id=wWciAQAAQBAJ&oi=fnd&pg=PA97&dq=manufacture+costs+of+batteries&ots=nENyCiJlOe&sig=gDffPFfZhPzD0tqojKa8ihb2ab4#v=onepage&q=manufacture%20costs%20of%20batteries&f=false

Lithium-Ion Batteries: Advances and Applications -
https://books.google.co.uk/books?hl=en&lr=&id=wWciAQAAQBAJ&oi=fnd&pg=PP1&dq=manufacture+costs+of+batteries&ots=nENyCiLqQa&sig=PQdM_W8OafRVbw3RQrrJWWjlQHM#v=onepage&q=manufacture%20costs%20of%20batteries&f=false

An Evaluation of Current and Future Costs for Lithium-Ion Batteries for Use in Electrified Vehicle Powertrains - https://dukespace.lib.duke.edu/dspace/handle/10161/1007

4.b Energy costs

Cell Chemistry	$/kWh	£/kWh	Year Commercialized

Lead-acid	56–145	43.36-112.29	1881
Zinc-carbon	316	2.6524	1898
Zinc-air	361	279.49	1932
Mercury oxide-zinc			1942–1996
Alkaline	2023	1566	1949
Rechargeable alkaline			1992
Silver-oxide			1960
Nickel-zinc			2009
Nickel-iron	178–238	138 -184	1901
Nickel-cadmium			1960
Nickel-hydrogen			1975
Nickel-metal hydride	297	229	1990
Low self-discharge nickel-metal hydride			2005
Lithium-manganese dioxide			1976
Lithium-carbon monofluoride			1976
Lithium-iron disulfide			1989
Lithium cobalt oxide	356	275	1991
Lithium iron phosphate			1996
Lithium manganese oxide	$356.00	275.37	1999
Lithium nickel cobalt aluminum oxide			1999
Lithium nickel manganese cobalt oxide			2008

Chart prediction over time…

X Axis - Year Commercialized
Y Axis - £/kWh

4.c.Specific Power

Cell Chemistry	Power (W/Kg)	Year Commercialized
Lead-acid	180	1881
Zinc-carbon	10–27	1898
Zinc-air	100	1932
Mercury oxide-zinc		1942–1996
Alkaline	50	1949
Rechargeable alkaline		1992
Silver-oxide		1960
Nickel-zinc		2009
Nickel-iron	100	1901
Nickel-cadmium	150–200	1960

Nickel-hydrogen	150–200	1975
Nickel-metal hydride	250–1000	1990
Low self-discharge nickel-metal hydride	250–1000	2005
Lithium-manganese dioxide	250–400	1976
Lithium-carbon monofluoride	50–80	1976
Lithium-iron disulfide		1989
Lithium cobalt oxide		1991
Lithium iron phosphate	200	1996
Lithium manganese oxide		1999
Lithium nickel cobalt aluminum oxide		1999
Lithium nickel manganese cobalt oxide		2008

//Insert graph here

4.d.Energy Density

Cell Chemistry	Wh/kg	Wh/L	Year Commercialized
Lead-acid	30–40	60–75	1881
Zinc-carbon	36	92	1898
Zinc-air	442	1,673	1932
Mercury oxide-zinc	99–123	300–500	1942–1996
Alkaline	85–190	250–434	1949
Rechargeable alkaline			1992
Silver-oxide	130	500	1960
Nickel-zinc			2009
Nickel-iron	19–25	125	1901
Nickel-cadmium	30	100	1960
Nickel-hydrogen	45–65	60	1975
Nickel-metal hydride	100	401	1990
Low self-discharge nickel-metal hydride	95	353	2005
Lithium-manganese dioxide	150–330	300–710	1976
Lithium-carbon monofluoride	260–780	440–1,478	1976
Lithium-iron disulfide	297	580	1989
Lithium cobalt oxide	195	560	1991
Lithium iron phosphate	90–130	333	1996
Lithium manganese oxide	150	420	1999
Lithium nickel cobalt aluminum oxide	220	600	1999

Lithium nickel manganese cobalt oxide	205	580	2008

//Insert graph here

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5. National Grid (Transmission lines)

5.a. Network Size
5.b. Power flow
5.c. Losses
5.d. Interconnects
5.e. Current Energy Costs
5.f. Past Energy Costs

5.a.Network Size

- Maximum demand (2005/6): 63GW (81.39% of capacity)
- UK Annual electricity: 360 TWh
- Capacity (2005/6): 79.9 GW
- Total large power stations connected: 181
- 400 kV grid Length: 11,500 km (circuit)
- 275 kV grid Length: 9,800 km (circuit)
- 132 kV grid Length: 5,250 km (circuit)

- 2005 Seven Year Statement (SYS)

5.b.Power flow

An average of 11-12GW of power from the north of the UK (scotland and northern england) flows to the south england across the grid, power generation in the south is around 12% more effective due to reduced power losses when transmitted.

https://en.wikipedia.org/wiki/National_Grid_(Great_Britain)

5.c.Losses

Heating of cables - 857.8MW

Fixed losses (corona and iron loss): 266MW

Transformer in substation heating loss: 142.4MW

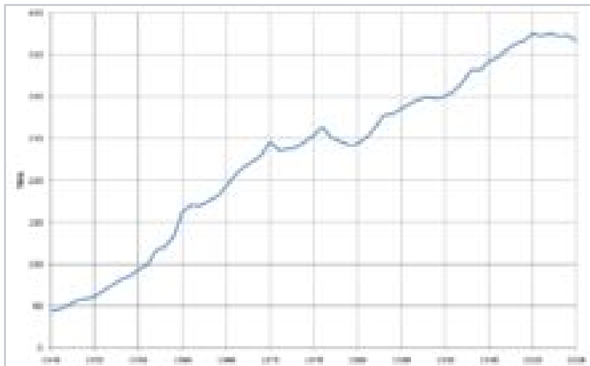
Transformer in generator heating loss: 157.3MW

Total Losses: 1423.5MW

Considering losses in electricity distribution to the consumer we lose around 7.7% of total power, for different consumers these losses vary, the higher the voltage the lower the losses, at high voltages consumers lose around 2.6%, medium voltages around 6.4% and at lower voltages consumers lose around 12.2%

Figures are again from the 2005 SYS.

According to Appendix A of[19] and of,[20] generated power entering the Grid is metered at the high-voltage side of the generator transformer. Any power losses in the generator transformer are therefore accounted to the generating company, not to the Grid System. The power loss in the generator transformer does not contribute to the Grid losses.



[edit]

5.d.Interconnects

The UK grid is connected to european and irish grids through submarine power cables at an electricity 6% interconnection level. DC cables connect UK grid to northern france, netherlands, northern ireland & republic of ireland.

A 40MW AC cable connects UK grid to the isle of man.

In the future the UK will connect with Belgium (Nemo link), Norway (1.4GW NSN Link), Denmark (1.4GW Viking Link). A second link with france and iceland. Scotland and wales (2.2GWwestern HDVC link)

5.e.Current Energy Costs -

Graph below indicates that electricity on average costs 15.4p per kWh:

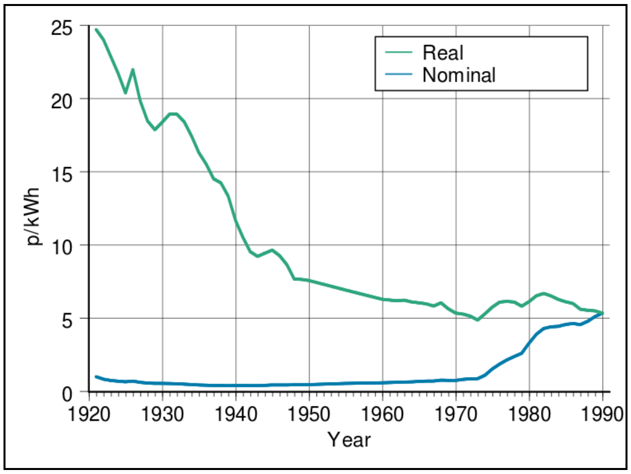
Taken from another source to confirm the above graph is correct, we can say that the average cost of a kWh is around 14-18p.

	Standard Credit	Direct Debit	Overall
+ Unit (kWh) cost	16.42 pence	14.71 pence	15.41pence
+ Average annual cost	£ 624	£ 559	£ 586

UK Average Electricity Prices per kWh and annual cost each year.-
https://www.confusedaboutenergy.co.uk/index.php/domestic-fuels/fuel-prices

5.f.Past Energy Costs

1920 -1990



1991 - 2016

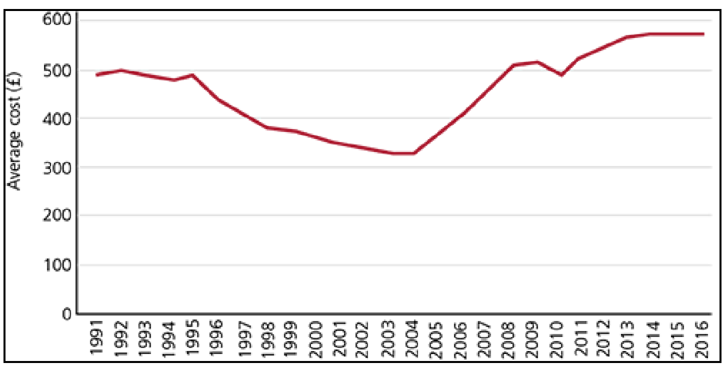
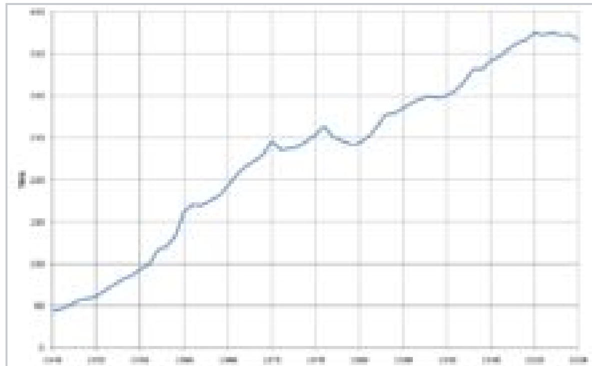


Figure 1: Average annual domestic electricity bills for a typical consumer in the UK, 1991 to 2016 (£, 2010 prices)18 https://publications.parliament.uk/pa/ld201617/ldselect/ldeconaf/113/113.pdf



5.g.Transmission costs

Tarriffs are set annually by the National Grid Electricity Transmission PLC (NGET), they depend on the zone you are in (the country is divided into different zones), each has a different tarriff for generation and consumption - tarriff are high for generators in the north and consumers in the south because of the north-south flow of electricity (consumers in the south pay more for electricity), the additional stresses increase demand and therefore price.

5.h.Triad demand

Triad demand is the average demand of the system over 90 minutes (three half hours) between november and february. These three half hours comprise the half hour of system demand peak and the other half hours of highest system demand which are separated from system demand peak and each other by at least ten days.

In April of each year, each licensed electricity supplier (such as Centrica, BGB, etc.) is charged a yearly fee for the load it imposed on the grid during those three half-hours of the previous winter. Exact charges vary depending on the distance from the centre of the network, but in the South West it is £21,000/MW.[citation needed] The average for the whole country is about £15,000/MW. This is a means for National Grid to recover its charges, and to impose an incentive on users to minimise consumption at peak, thereby easing the need for investment in the system. It is estimated that these charges reduced peak load by about 1 GW out of say 57 GW.[citation needed]

This is the main source of income which National Grid uses to cover its costs and these charges are commonly also known as Transmission Network Use of System charges (TNUoS). (Note this is for high voltage long distance transmission and the lower voltage distribution is charged separately.) The grid also charges an annual fee to cover the cost of generators, distribution networks and large industrial users connecting.

These Triad charges encourage users to cut load at peak periods; this is often done using diesel generators. Such generators are also routinely used by National Grid.[35]

Estimating costs per kWh of transmission

To estimate the cost of the a kWh of electricity:

TNUoS = £15,000/MW year x 50,000MW = £750Million/Year

Total No of Units = 360tWh (1.3EJ)

Transmission costs = 0.2p/kWh

5.i.Overview

Maximum demand (2005/6): 63 GW (81.39% of capacity)
Capacity (2005/6): 79.9 GW
UK Annual electricity: 360 TWh
Total Losses: 1423.5MW
Overall Power Flow: 11-12GW

Transmission Costs = 0.2p/kWh

Costs per kWh: 15.4p

Energy transportation costs “ The cost of transporting electricity is predicted to rise by around 8-15%”

https://www.ukpower.co.uk/home_energy/future-gas-electricity-price-forecast

Gas and Oil Prices -“The growing use of sustainable energy suppliers is slowly beginning to decrease our reliance on gas and coal but this is a costly business.”

From previous electricity costs and the information above and in the previous section we can predict future energy costs

7. Consumer demands and expenses

Demand - ”It has been predicted that there will be a 35% increase in energy requirement by 2040.”

2005 annual demand: 360TWh

2040 UK annual demand: 360TWh * 135% = 486TWh

Difference between demands: 126TWh

Every 5 years there will be a (126TWh/7 = 18TWh) Increase in energy demands:

2005: 360TWh	2010: 378TWh	2015: 396TWh	2020: 414TWh	2025: 432TWh	2030: 450TWh
2035: 468TWh	2040: 486TWh	2045: 504TWh	2050: 522TWh	2055: 540TWh	2060: 558TWh
2065: 576TWh					

National Grid:

Battery Cell Technology:

At what year could the weight and volume of these batteries be small/portable enough to fit in households and power the average house in the UK? Considering the desirable weight and volume in the UK...

The average house in the UK in 2017 uses …… watts per year, but from future values of consumer usage as predicted above the battery would need to supply …… watts per year, considering how much weight could be transported by a consumer (for example 50kg) I can calculate by ….. portable batteries will advance (based off my calculations of energy density) much that they replace transmission lines.

9. Hypothesis

Bibliography

Checklist

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