Lost potential: how the kidnapping of a solar energy pioneer impacted the cost of renewable energy and the climate crisis

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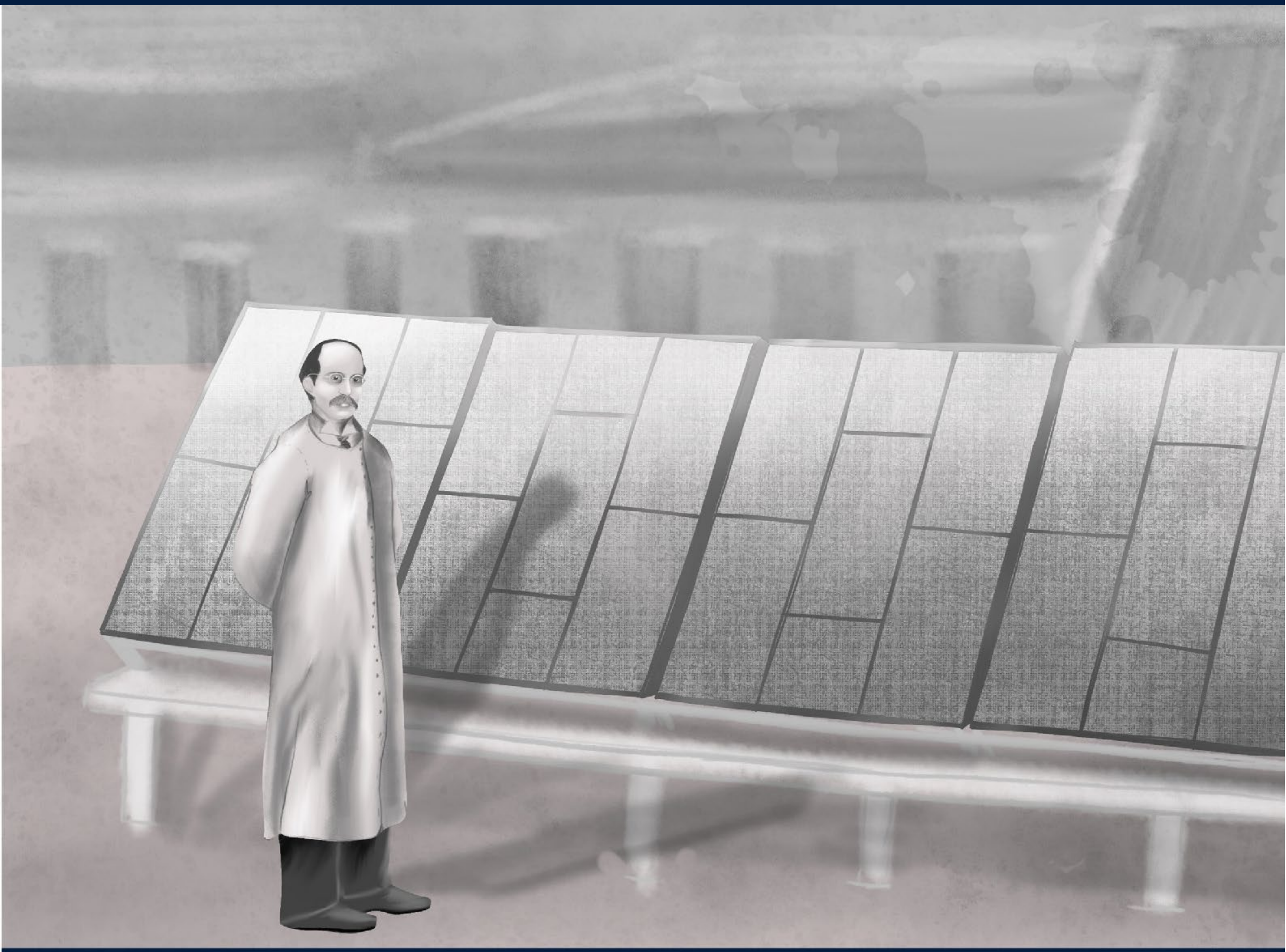
Oxford Smith School of Enterprise and the Environment



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Overview

This thought piece draws on historical records, newspaper archives and modern analysis to explore the story of George Cove – a renewable energy inventor and entrepreneur who lived in the early 1900s – and its relevance to today's clean energy transition.

George Cove had a patent for his solar energy device and a registered company called "Sun Electric Generator Corporation". Cove's invention could produce electricity by harnessing the photovoltaic effect and power small household devices.

The idea was to sell his device through a corporation and pursue further inventive activity to make the solar panel more efficient. However, this novel idea, which had attracted noteworthy investors and captured the imagination of many science writers and general newspapers of the time, would be prematurely terminated. George Cove was kidnapped and told to give up his patents and shut down his business.

Contemporaries like Edison Electric were building out the power grid using coal-fired electricity and Standard Oil was consolidating its hold over the market by buying out any type of competitor at the time. Ruthless practices to drive out competitors were commonplace during this period of history.

George Cove's Sun Electric corporation never recovered from the kidnapping and the "fantastic sun ray machine" was forgotten. From the demise of Sun Electric in 1910-11, it would take another 40 years for Bell Labs to invent the practical silicon solar cell, 60 years for NASA to use solar panels for space probes, and 100 years for the United Kingdom to install its first ever utility-scale solar farm.

How would the world have looked had there been no disruption in solar power development, if Sun Electric had continued to operate as company and innovate in solar panels? What if Sun Electric became a household name the same way Edison Electric did? This thought experiment explores a forgotten history of solar power and questions how the world may have looked had these early efforts been nurtured and supported.

Using a set of conservative assumptions, it finds that solar PV could have become cheaper than coal at least a decade sooner, which would have limited the rapid expansion of coal capacity in early 2000s. However, this thought exercise is subject to the usual critiques of any counterfactual estimation. What is far less debatable is that there was an ambitious vision of a solar powered world in the early 1900s that disappeared for many decades and is only being resurrected today.

Executive Summary

1. George Cove, a Canadian inventor who is widely forgotten today, created a solar panel in the early 1900s and demonstrated it on New York's rooftops.[1] The device was granted patent protection in 1906[2] and Cove was to sell it through his solar venture, "Sun Electric Generator Corporation" which was capitalised at 5 million USD.[3]
2. The solar invention received wide media coverage in early 1909. Technical magazines and newspapers in faraway foreign locations such as Australia were gushing about the invention and imagining a world powered by the fantastic "sun ray machine".[4] Commentators discussed the possibility of this invention leading to abundant cheap power that would free households from energy poverty.[5,6]
3. In the autumn of 1909, a few months after the spike in media attention, George Cove was kidnapped and offered ransom on the condition that he shut down his solar business and forgo his patents.[7] Although not all agree, some sources speculate the kidnapping was the product of vested interests.[8] During that time, Thomas Edison (of Edison Electric) and J.D. Rockefeller (founder of Standard Oil) were known to deploy a variety of pernicious tactics to drive competitors out of business.[9]
4. George Cove's solar business ceased after the kidnapping. While some scattered efforts in solar photovoltaic development occurred, there were no major commercial or inventive activities for the next 4 decades until Bell Labs invented the practical solar cell in 1954. Coal-fired power and oil grew at unprecedented pace in those interim decades.
5. Leveraging Wright's Law, which is the empirical observation that with every doubling of cumulative capacity there is a decline in costs (due to learning),[10] this paper conducts a hypothetical thought experiment on what solar costs may look like today had there been no obstruction in solar power development, that is, if the Sun Electric survived alongside Edison Electric and Standard Oil. Using a set of conservative assumptions, it speculates that solar power may have become cheaper than coal in the early 2000s rather than in 2016. Between 2000-2016 coal grew by 50%[11] – something that may not have happened

[1] Low-Tech Magazine (2021). "How to Build a Low-Tech Solar Panel." https://www.lowtechmagazine.com/2021/10/how-to-build-a-low-tech-solar-panel.html
[2] Cove, G. (1906). Thermo-electric battery and apparatus (Patent No. US824684A). United States Patent and Trademark Office.
[3] Bartels, D. (1997). "George Cove's Solar Energy Device". Material Culture Review 46 (1).
[4] René Homer (1909). "Harnessing sunlight", Modern Electrics, Vol. II, No.6, September p. 234-244; Winthrop Packard (1909), "Power From Sunlight," The Technical World Magazine 11, no. 4, 358-360.
[5] The World's News. (1909, May 8). Electricity from the Sun's Rays. Sydney. Accessible here: https://trove.nla.gov.au/newspaper/article/133971505
[6] René Homer (1909). "Harnessing sunlight", Modern Electrics, Vol. II, No.6, September p. 234-244 Accessible here: https://babel.hathitrust.org/cgi/pt?id=mdp.39015051407073&view=1up&seq=5&skin=2021
[7] "Kidnapped: A Story about an Inventor." (1909, October 19). The New York Herald as cited here.
[8] Bartels, D. (1997). "George Cove's Solar Energy Device". Material Culture Review 46 (1).
[9] Richardson, V. & Roy, C. (Hosts). (2018, March). John D. Rockefeller) [Audio podcast episode]. Historical Figures. Parcast.; Richardson, V. & Roy, C. (Hosts). (2018, May). Thomas Edison [Audio podcast episode]. Historical Figures. Parcast.
[10] This relationship was first observed for aeroplanes: Wright, L. (1936). "Factors Affecting the Cost of Airplanes." Journal of the Aeronautical Sciences, 3(4), 122-128 and then more broadly discussed: Arrow, K. J. (1962). "The Economic Implications of Learning by Doing." The Review of Economic Studies, 29(3), 155-173.
[11] Data from BP Statistical Review of World Energy, presented by Our World in Data.

had solar been cheaper, and which has implications for greenhouse gas emission levels and air pollution.

6. George Cove was a serial inventor, and was said to have inherited his talents from his father who was also a “mechanical genius”.[12] Cove was a renewable energy visionary who also had a patent for “tide power” at the Canadian patent office.[13]
7. Obstructionism has been a key barrier to the development and deployment of renewable energy in the past and continues to be so today.[14]

[12] The World's News. (1909, May 8). Electricity from the Sun's Rays. Sydney. Accessible here: https://trove.nla.gov.au/newspaper/article/133971505
[13] Cove, G. (1906). Tide Power System (Patent No. 100247). Canada Patent Office. See here.
[14] Srivastav, S. and Rafaty, R., 2022. Political Strategies to Overcome Climate Policy Obstructionism. *Perspectives on Politics*, pp.1-11.

The Story of the World's First Solar Inventor

"The aeroplane of the future will dart hither and thither, her motors driven by electric energy transmitted by wireless from some far-away Sun Electric power plant".[15]

Take a moment to imagine when this statement was made. It is referring to an aeroplane that is not powered by jet fuel, as we know planes to be, but by batteries that have been charged using solar energy produced by a company called Sun Electric.

The idea sounds futuristic and you might guess, noting the use of the anachronistic "hither and thither", that some visionary said in this in the 1970s, around the time NASA was working on solar power for space. Perhaps you might be more ambitious and guess that someone at Bell Labs made the statement in the 1950s when the first practical silicon cell was invented. However, both of these guesses would be wrong. This remarkable statement was made in 1909 by Rene Homer in an article titled, "Harnessing Sunlight".[15] Rene was writing about an important yet forgotten inventor, George Cove.

George Cove was from Nova Scotia in Canada and emigrated to the US to pursue a career as an inventor. He was the son of Joseph Cove, who was lauded as a "mechanical genius".[16] George Cove filed numerous patents over his lifetime which contained novel ideas related to changes in propeller design[17], harnessing solar energy[18], tapping tidal power,[19] creating electric clocks and watches,[20] and improving upon the alternating current generator, first invented by Nikola Tesla.[21] George Cove had ambitions to commercialise these technologies and was particularly passionate about his solar device.

George Cove's solar patent, around which he created the company "Sun Electric", describes an invention which, *"...given two days' sun… will store sufficient electrical energy to light an ordinary house for a week".* [15] In a demonstration in 1910, pictured below, Cove mounted the solar panels on a rooftop and angled them appropriately to capture sunlight. The invention piqued the interests of investors and Sun Electric was capitalised at $5 million.[3]

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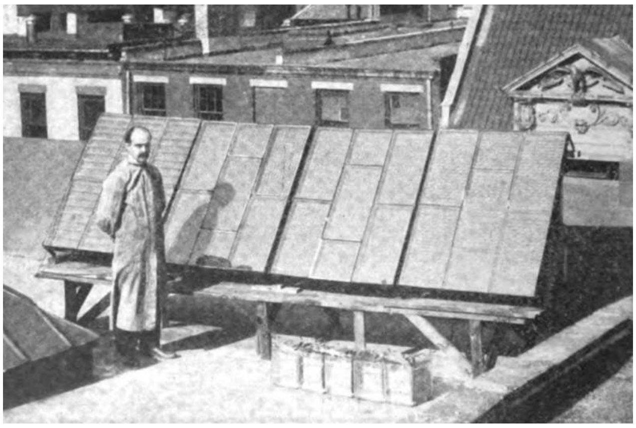
[15] René Homer (1909). "Harnessing sunlight", Modern Electrics, Vol. II, No.6, September p. 234-244; Winthrop Packard (1909), "Power From Sunlight," The Technical World Magazine 11, no. 4, 358-360.
[16] The World's News. (1909, May 8). Electricity from the Sun's Rays. Sydney. Accessible here: https://trove.nla.gov.au/newspaper/article/133971505
[17] Cove, G. (1901). Propeller (Patent No. US673468A). United States Patent and Trademark Office.
[18] Cove, G. (1906). Thermo-electric battery and apparatus (Patent No. US824684A). United States Patent and Trademark Office.
[19] Cove, G. (1906). Tide Power System (Patent No. 100247). Canada Patent Office.
[20] Cove, G. (1916). Clock or watch (Patent No. US1175610A). United States Patent and Trademark Office.
[21] Cove, G. (1907). Alternating-current generator (Patent No. US870938A). United States Patent and Trademark Office.

Figure 1. The World's First Rooftop Solar System, 1910



George Cove stands next to his third solar array. Source: "Generating electricity by the sun's rays", Popular Electricity, Volume 2, nr. 12, April 1910, pp.793.

In terms of scientific principles, Cove's solar device was aligned with modern day understandings of how to harness the photovoltaic effect. Cove had purportedly created a semiconductor with a bandgap of 1.2 eV, which is very close to the bandgap of silicon (1.1 eV), which is the primary material used in solar panels today.[22] This was the outcome of trial and error since our understanding of the photovoltaic effect was just emerging at the time. Cove had observed experimentally that as he changed the materials, the proportion of energy coming from sun rays increased and that which was related to heat diminished.

George Cove also thought about the intermittency problem and built in a battery:

> *"with a 'solar electric generator,' it is possible to trap [the Sun's rays], store them in any good form of storage battery…and turn them on at will to do the desired work."*[15]

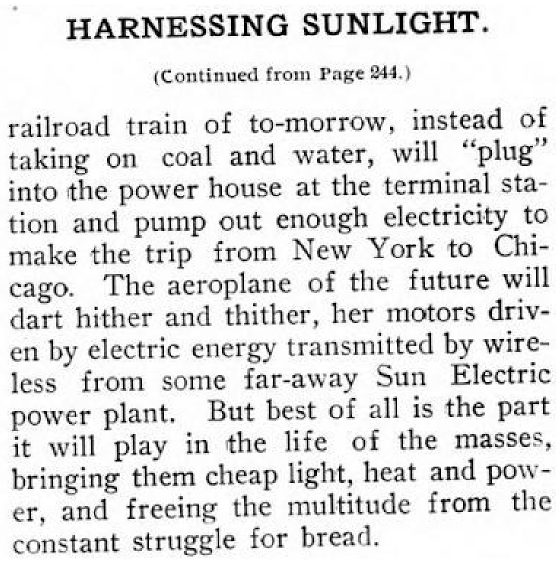
This invention took the world by storm and news of Cove's device started gaining global traction. On 8 May 1909, an Australian newspaper noted that George Cove's machine could be built at a cost of $20 ($660 in today's terms), last for ten years, and supply enough electricity for the house, without the need for any wires (a reference to the transmission and distribution network that was being built out at the time and which relied on coal-based electricity).[23]

The enthusiasm around Cove's invention and vision for a solar powered world can be seen in Figure 2, which contains a snapshot of an article from 1909, which talks about how solar

[22] Low-Tech Magazine (2021). "How to Build a Low-Tech Solar Panel." https://www.lowtechmagazine.com/2021/10/how-to-build-a-low-tech-solar-panel.html
[23] The World's News. (1909, May 8). Electricity from the Sun's Rays. Sydney. Accessible here: https://trove.nla.gov.au/newspaper/article/133971505

power will bring the masses cheap and affordable electricity and remove dependence on coal. Outlets also noted how inventiveness ran in Cove's blood since his father was an inventor too.[24]

Figure 2. Media Response to Cove's Solar Invention



HARNESSING SUNLIGHT.

(Continued from Page 244.)

railroad train of to-morrow, instead of taking on coal and water, will "plug" into the power house at the terminal station and pump out enough electricity to make the trip from New York to Chicago. The aeroplane of the future will dart hither and thither, her motors driven by electric energy transmitted by wireless from some far-away Sun Electric power plant. But best of all is the part it will play in the life of the masses, bringing them cheap light, heat and power, and freeing the multitude from the constant struggle for bread.

Extract from University of Michigan Digital Archives describing the envisaged potential of solar power from *René Homer (1909). "Harnessing sunlight", Modern Electrics, Vol. II, No.6, September p. 234-244.*

However, Cove's success may have brought on a new type of threat. In October 1909, George Cove was allegedly kidnapped by two men. According to a report in *The New York Herald* on 19 October 1909 (Figure 3), Cove's kidnappers asked him to give up the rights to his solar patent and close down his business. Cove refused and was later released near Bronx zoo.

Some allege Cove staged the incident to get media attention.[25] However, Cove's solar invention was already widely covered by technical magazines, local newspapers and even foreign media outlets. Others hypothesize that vested interests were at play because "off-grid solar" would threaten the business models of companies like Standard Oil and Edison Electric, that were using oil and coal-fired powerplants to meet people's growing power needs.[26] The unscrupulous practices of Edison Electric and Standard Oil to wipe out competitors were well known. Edison electrocuted cats, dogs, horses, an elephant and even a prisoner on death row with an alternating current to discredit his competitor Nikola Tesla[27]

[24] The World's News. (1909, May 8). Electricity from the Sun's Rays. Sydney. Accessible here: https://trove.nla.gov.au/newspaper/article/133971505
[25] Bartels, D. (1997). "George Cove's Solar Energy Device". Material Culture Review 46 (1).
[26] Bartels, D. (1997). "George Cove's Solar Energy Device". Material Culture Review 46 (1).
[27] Richardson, V. & Roy, C. (Hosts). (2018, May). Thomas Edison [Audio podcast episode]. Historical Figures. Parcast.

while Standard Oil's aggressive practices of driving out competition created the foundation of modern anti-trust and anti-monopoly legislation. [28]

Figure 3. Newspaper clipping of George Cove's Kidnapping

KIDNAPPED; A STORY ABOUT AN INVENTOR

Being a Veracious Account of How Two Desperate Men Abducted Little Mr. Cove.

SAYS HE CAN TAP THE SUN

Wilfred Doe (Not Related to the Justly Celebrated John) Starts Sleuths on the Trail.

The whole Police Department of New York got worked up yesterday over an alleged kidnapping case. While the mystery lasted Police Headquarters was at fever heat and when it was all over and the kidnapped person found there yet remained a suspicion in the minds of all the sleuths concerned that they had been

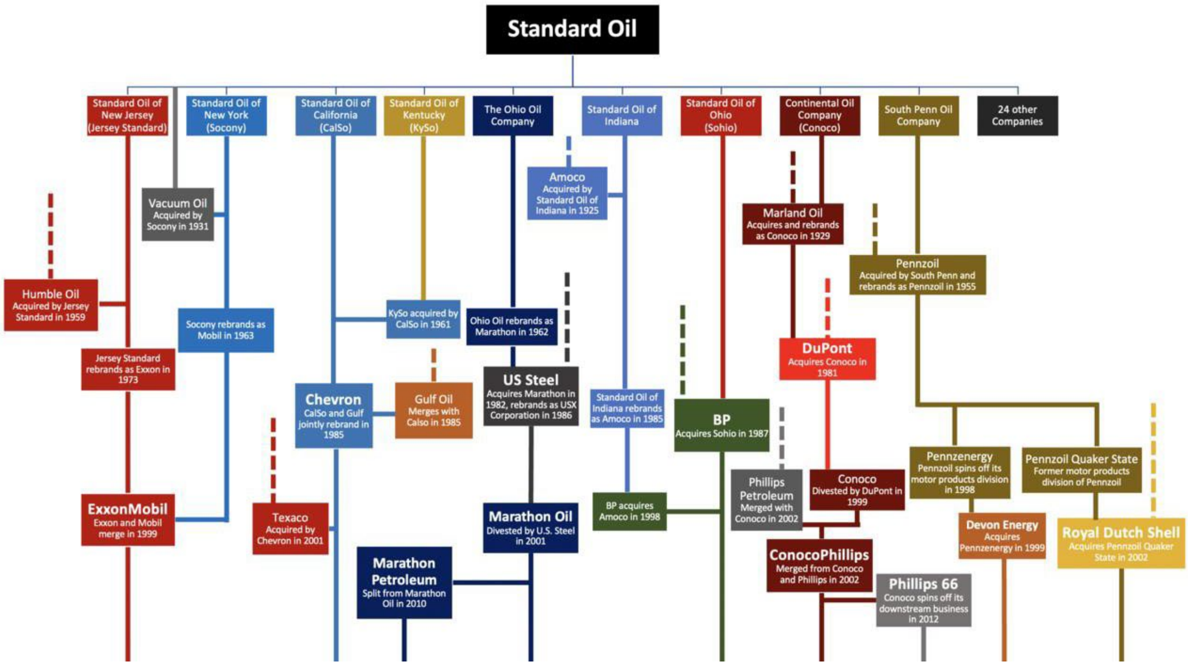
The New York Herald on 19 October 1909

Unfortunately, after the kidnapping, George Cove's business, Sun Electric, dwindled out and was even de-registered. Therefore, despite the fact that Cove's solar panel came only 23 years after the first coal- fired power station (Pearly Street Station, 1882, Edison Electric), the technology remained in oblivion for decades and George Cove became a forgotten entity. From 1910, it would take 40 years for Bell Labs to invent the silicon solar cell, 60 years for NASA to use solar for space probes, and 100 years for the United Kingdom to install its first ever utility-scale solar farm. It is also possible that the kidnapping spooked other inventors from trying their hand at solar technology.

Meanwhile, Edison Electric and Westinghouse Electric would grow the coal-based power grid, and Standard Oil would become so large that the US government was forced it to break up, creating many of the descendant oil giants that we know today (see Figure 4).

Figure 4. The Corporate Descendants of John D. Rockefeller's Standard Oil Corporation

[28] Richardson, V. & Roy, C. (Hosts). (2018, March). John D. Rockefeller (No. 22) [Audio podcast episode]. Historical Figures. Parcast.



Thought Experiment

What would have happened had Sun Electric survived? Where would we be today if the world had supported George Cove's inventive activity in solar power development? Records show that Cove went through at least 3 iterations of the solar device and each time it became better. This is a commonly observed phenomenon captured by the concept of an "experience curve", which was first documented for aeroplanes. It turned out that with each doubling of produced aeroplane capacity, unit costs would fall by a relatively predictable percentage.[29] This became known as Wright's Law and has been observed for a wide range of technologies, including solar power.[30] With every doubling of cumulative solar photovoltaic capacity, costs have come down by 20%.[31]

Experience curves elucidate how with more production (i.e. "experience"), managers become more competent, new ideas emerge for process and product improvements, and economies of scale kick in. All of these factors reduce unit costs.[32] Experience curves have been utilised

[29] Wright, L. (1936). "Factors Affecting the Cost of Airplanes." Journal of the Aeronautical Sciences, 3(4), 122-128
[30] Way, R., Ives, M. C., Mealy, P., & Farmer, J. D. (2022). Empirically grounded technology forecasts and the energy transition. *Joule*, *6*(9), 2057-2082.
[31] Way, R., Ives, M. C., Mealy, P., & Farmer, J. D. (2022). Empirically grounded technology forecasts and the energy transition. *Joule*, *6*(9), 2057-2082..
[32] Lafond, F., Greenwald, D. and Farmer, J.D., 2022. Can stimulating demand drive costs down? World War II as a natural experiment. *The Journal of Economic History*, *82*(3), pp.727-764.

by researchers at the University of Oxford to forecast different technologies' costs in a way that has outperformed most other forecasting methods.[33]

What if we use the experience curve to estimate what solar costs *would have been* today had solar development continued since 1910? A simple thought experiment could involve assuming that there was no 40-year hiatus in solar power development, and use the experience curve to project "where we could have been". Exploring this is the goal for the remainder of this paper.

Methods, Results and Caveats

To estimate what the cost of electricity from solar photovoltaic *would have been*, this analysis back-casts solar PV's experience curve. In order to do this, assumptions are required around: learning rates (by how much did costs fall with each doubling of solar PV capacity?), initial conditions on quantity and price (how much solar technology was Sun Electric initially producing and at what cost?), and growth rates (how fast did solar technology grow in this hypothetical world?)

Historical data on solar PV costs and cumulative installed capacity are obtained from Way et al (2023), [34] who in turn get this data from multiple academic studies, industry reports, and government databases. This (vetted) data spans from 1976 to 2020 and is used to estimate the experience curve for solar PV. It is found, in line with the literature, that with every doubling of solar PV capacity, there is a 20% decline in costs.[35] Therefore, a 20% learning rate is used in this back-casting exercise. The focus is on solar PV rather than solar thermal since Cove's device leveraged the photovoltaic effect.[36]

For assumptions around initial conditions, since there is no data on the cost of solar power from Cove's device in terms of USD/MWh, this analysis takes the estimated experience curve[37] to back-cast an initial cost given the initial assumed capacity. For initial quantity, two scenarios are explored.

In **Scenario A**, it is assumed that George Cove's company, in 1910, produced a very modest capacity of solar PV at 1,000 kWh. This is equal to one-tenth of the annual electricity

[33] Way, R., Ives, M. C., Mealy, P., & Farmer, J. D. (2022). Empirically grounded technology forecasts and the energy transition. *Joule*, *6*(9), 2057-2082..
[34] Way, R., Ives, M. C., Mealy, P., & Farmer, J. D. (2022). Empirically grounded technology forecasts and the energy transition. *Joule*, *6*(9), 2057-2082..
[35] Way, R., Ives, M. C., Mealy, P., & Farmer, J. D. (2022). Empirically grounded technology forecasts and the energy transition. *Joule*, *6*(9), 2057-2082.
[36] Low-Tech Magazine (2021). "How to Build a Low-Tech Solar Panel." https://www.lowtechmagazine.com/2021/10/how-to-build-a-low-tech-solar-panel.html
[37] Wright's law (the experience curve) is given by *y=ax^b,* where *y* is cost, *a* is a constant, *x* is cumulative capacity and *b* is the exponent that describes the learning rate. The constant, *a*, and learning rate, *b*, are estimated from real data on costs and cumulative capacity.

consumption of a single American household today (or 0.2% of the electricity produced from solar PV in 1976, which is the first data point we have on annual solar PV electricity production).

In **Scenario B**, it is assumed the starting point is a production capacity of 5,000 kWh or in other words, half the amount of power used by a single modern American household. This represents a conservative yet slightly more optimistic estimate of Sun Electric's initial solar PV production.

For growth rates, this analysis assumes that solar PV grows very slowly in the experimental stage, then enters a faster uptake period, and ultimately slows down again as the market saturates. More precisely, it is assumed that the annual growth rate of solar PV production is: 3% from 1910-40, 10% from 1940-50, 30% from 1950-60, 50% from 1960-80, and 35% from 1980 to 2020. The actual average year on year change in cumulative capacity is around 45% from 1976-2021.[38]

Since these growth rates are important for the final results, they warrant some further explanation. It is assumed solar PV grew at 3% in the first three decades because in the early 20th century, the world did not have modern computing power, semiconductors, and other technologies that are complementary to solar PV.[39] However, since the direction of technological progress is endogenous,[40] it could be argued that had solar PV taken off in 1910, the direction of subsequent inventive activity would have evolved to support solar – this would plausibly justify growth rates higher than 3%. This analysis errs on the side of being conservative and keeps the assumption of 3% in the first three decades. A 10% growth rate is assumed for 1940-50s because during World War II, significant technological leaps were made in domains complementary to solar PV, most notably, semiconductors. The subsequent growth rates come closer to what was empirically observed.

With these assumptions, this analysis finds that solar PV would have become cheaper than coal by the early 2000s as opposed to in 2016. In Scenario A, solar becomes cheaper than coal in 2007 (9 years earlier). In Scenario B, it becomes cheaper in 2002 (14 years earlier). In reality, in about 2016, the levelized cost of electricity from coal was around 100 USD/MWh and likewise for solar PV. In the Cove counterfactual, the 2016 cost of electricity from solar PV is USD 24-40 per MWh, which is 2-4 times cheaper (the ranges reflect the two scenarios).

[38] More sophisticated approaches can be used for modelling the counterfactual diffusion of solar (e.g. one could assume a smooth S-curve for diffusion), but for the sake of simplicity and accessibility, this approach has been used.
[39] Pichler, A., Lafond, F. and Farmer, J.D., 2020. Technological interdependencies predict innovation dynamics. *arXiv preprint arXiv:2003.00580*.
[40] Acemoglu, D., Aghion, P., Bursztyn, L. and Hemous, D., 2012. The environment and directed technical change. *American economic review*, *102*(1), pp.131-166.

Potential implications of cheaper solar PV

What are the implications of solar PV that is cheaper far sooner?

Consider, for example, that Al Gore's 'An Inconvenient Truth' came out in 2006. If solar had already been cheaper than coal at that time, the trajectory of climate action may have looked very different.

Between 2000 and 2016, coal-fired capacity grew by around 50% from 28,000 TWh to 43,000 TWh.[41] We know today that cheaper solar power has driven the rapid adoption of the technology and, in doing so, has displaced large quantities of coal-fired generation. Could this displacement effect have happened much sooner?

Further, coal-fired power is one of the deadliest energy technologies as it contributes to more deaths per MWh than any other type of energy.[42] Had the inflexion point for cost competitiveness been sooner, could there have been avoided deaths, due to much cleaner air? Further, studies have shown that cheaper costs help dissipate political conflicts in the energy transition[43] (and there have been significant instances of political conflict and lobbying to deter more stringent climate policy[44]). If solar power had become cheaper sooner, would there have been more windows of opportunity for pushing through ambitious climate and renewable energy policies?

Caveats

As with any type of back casting exercise, there are inherent limitations and uncertainties. These include measurement error and unknowns in the historical data, and the suitability of assumptions related to initial conditions, growth rates and learning rates.

For example, if we were to assume that from 1940-50, solar PV grew at 30% (instead of 10%), then the year in which solar overtakes coal, in terms of being cheaper, is 1997. Results are sensitive to these assumptions. There is a spreadsheet accompanying this thought piece where users can input their own assumptions and see how results change according to inputs they find most credible.

However, another way to view this thought experiment even more simply, is as follows: from the 1950's Bell Lab invention (the practical silicon solar cell), it took solar PV roughly 7 decades to become competitive against coal. If progress on solar PV had started four

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[41] Data from BP Statistical Review of World Energy, presented by Our World in Data. https://ourworldindata.org/grapher/coal-production-by-country?time=1987..latest&country=GBR~USA~CHN~IND~DEU~JPN~OWID_WRL

[42] https://ourworldindata.org/grapher/death-rates-from-energy-production-per-twh

[43] Brulle, Robert J. 2018. "The Climate Lobby: A Sectoral Analysis of Lobbying Spending on Climate Change in the USA, 2000 to 2016." Climatic Change 149, no. 3: 289–303 and Brulle, Robert J. 2019. "Networks of Opposition: A Structural Analysis of US Climate Change Countermovement Coalitions 1989–2015." Sociological Inquiry 91, no. 3: 603–24.

[44] Brulle, Robert J. 2018. "The Climate Lobby: A Sectoral Analysis of Lobbying Spending on Climate Change in the USA, 2000 to 2016." Climatic Change 149, no. 3: 289–303 and Brulle, Robert J. 2019. "Networks of Opposition: A Structural Analysis of US Climate Change Countermovement Coalitions 1989–2015." Sociological Inquiry 91, no. 3: 603–24.

decades earlier, in 1910, then perhaps it is not unreasonable to speculate that solar PV would have become cost competitive with coal at least one or two decades earlier.

Conclusion

No one can know with any certainty how solar PV's trajectory would have panned out if George Cove was not kidnapped. At one extreme, perhaps George Cove's invention did not mean anything and the trajectory of solar development would have played out in a way that looks similar to what actually happened. At another extreme, perhaps the solar era would have started far earlier, avoiding a numerous negative consequences of fossil fuel build out. The truth likely lies somewhere in the middle. Ultimately, no one holds the answers to what the world *could* have looked like, but what is known, with much more clarity, is that in 1909, there was a vision of a solar-powered world that was lost, and is only being revived now, more than 100 years later.

It is almost unimaginable that in 1909, journalists were writing about addressing energy poverty through solar energy and contemplating powering planes through solar-powered electric batteries (Fig. 2). These statements carried much more hope and optimism than articles written in 2010- 2014 (Fig 5).

While George Cove never got to realise his solar device's potential, solar power is now the cheapest form of electricity in the world[45], the IEA forecasts that renewable energy will become the largest source of global electricity generation by 2025,[46] and leading analysis shows how switching out to cleaner energy will result in net savings worth trillions of USD.[47] Humanity's ability to harness the power of the sun for a cleaner, greener and cheaper energy future may yet vindicate the kidnapped "Little Mr Cove"[7] as well as the science writers of the early 1900s who dared to dream of a solar powered world.

George Cove's kidnapping is perhaps the most poignant element of this story. The predatory practices of companies such as Edison Electric and Standard Oil were well known at the time. As much as one would like to view scientific activity as an endeavour that is separate and above the everyday struggles of power, perhaps George Cove's story best illustrates how it is very much embedded in such forces. Much like Nikola Tesla, who was a forgotten entity until Elon Musk revived his legacy by naming his electric vehicle company "Tesla", George Cove might also have to be resurrected to gain his rightful place in the history of the low-carbon energy transition.

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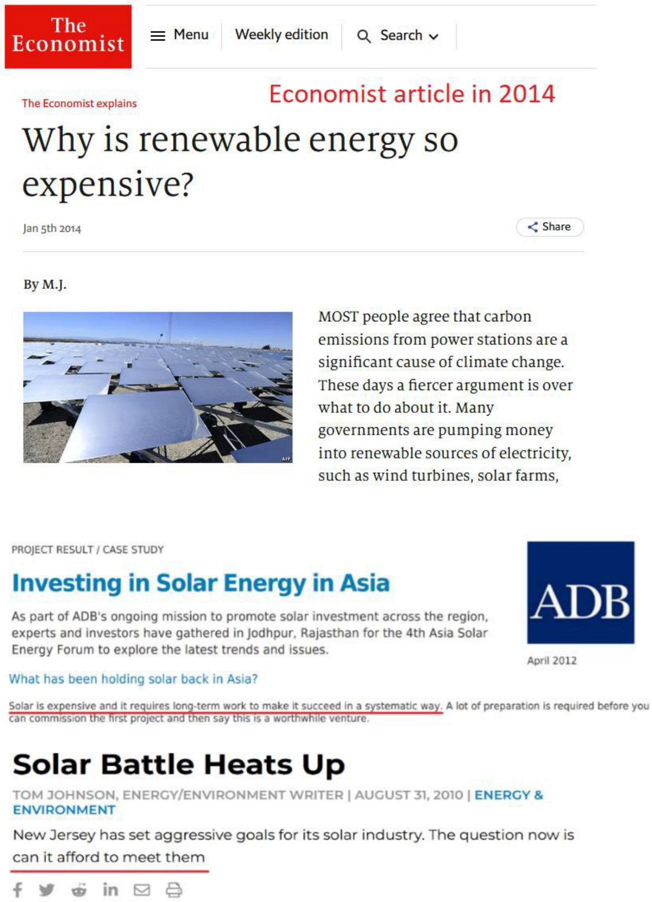
[45] IRENA. (2021). Renewable Power Generation Costs in 2021. Retrieved from https://www.irena.org/publications/2022/Jul/Renewable-Power-Generation-Costs-in-2021
[46] https://www.ft.com/content/98cec49f-6682-4495-b7be-793bf2589c6d
[47] Way, R., Ives, M. C., Mealy, P., & Farmer, J. D. (2022). Empirically grounded technology forecasts and the energy transition. *Joule*, *6*(9), 2057-2082.

Figure 5. Media Perceptions around Renewable Energy 2010-2014



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By M.J.

MOST people agree that carbon emissions from power stations are a significant cause of climate change. These days a fiercer argument is over what to do about it. Many governments are pumping money into renewable sources of electricity, such as wind turbines, solar farms,

PROJECT RESULT / CASE STUDY

Investing in Solar Energy in Asia

As part of ADB's ongoing mission to promote solar investment across the region, experts and investors have gathered in Jodhpur, Rajasthan for the 4th Asia Solar Energy Forum to explore the latest trends and issues.

ADB

April 2012

What has been holding solar back in Asia?

Solar is expensive and it requires long-term work to make it succeed in a systematic way. A lot of preparation is required before you can commission the first project and then say this is a worthwhile venture.

Solar Battle Heats Up

TOM JOHNSON, ENERGY/ENVIRONMENT WRITER | AUGUST 31, 2010 | ENERGY & ENVIRONMENT

New Jersey has set aggressive goals for its solar industry. The question now is can it afford to meet them

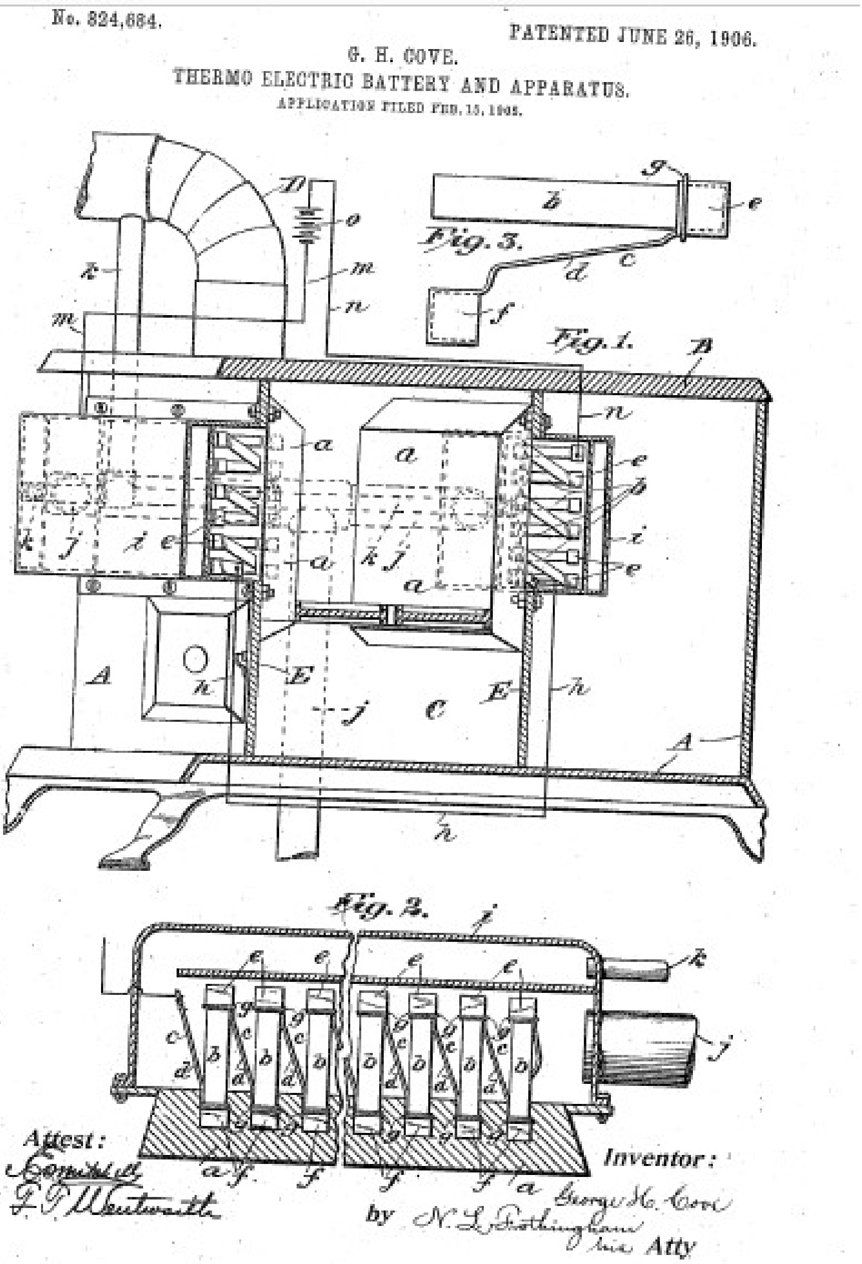
Acknowledgements and Disclaimers

The author would like to thank Francois Lafond, Lucy Erickson, Thomas Pilsworth, Tim Dobermann, Samira Barzin, Rupert Way and Lilliana Resende for their support and feedback. The author takes sole responsibility for any errors.

This piece is intended for a general audience. Its aim is to, first and foremost, tell the story of a forgotten inventor. The numerical analysis is presented is in the spirit of a thought experiment and the author claims no causality. Readers are encouraged to think critically about their own interpretations of the historical events presented in this brief.

Appendix

George Cove Solar Patent Documentation



UNITED STATES PATENT OFFICE.

GEORGE H. COVE, OF ROXBURY, MASSACHUSETTS, ASSIGNOR, BY DIRECT AND MESNE ASSIGNMENTS, OF ONE-HALF TO CHARLES M. BUNKER, AND ONE-HALF TO FRANK R. KIMBALL, OF BOSTON, MASSACHUSETTS.

THERMO-ELECTRIC BATTERY AND APPARATUS.

No. 824,684. Specification of Letters Patent. Patented June 26, 1906.

Application filed February 15, 1906. Serial No. 348,683.

To all whom it may concern:

Be it known that I, George H. Cove, a subject of the King of the United Kingdom of Great Britain, residing at Roxbury, in the county of Suffolk and State of Massachusetts, have invented certain new and useful Improvements in Thermo-Electric Batteries and Apparatus, of which the following is a specification, reference being had therein to the accompanying drawings, which form a part thereof.

The invention relates to thermo-electric batteries, and more particularly to the composition of the various elements and their arrangement with relation to the source of heat and each other. The underlying principles of batteries of this type are well-known in this art, and such will not, therefore, be referred to at length.

The object of this invention is to utilize these well-known principles in a manner to produce an external current capable of being employed advantageously in the useful arts.

A further object is to so arrange the various elements as to permit the subjection of one end or joint of each pair of elements to an intense constant heat, while permitting the other end or joint to be maintained at a relatively low temperature.

A still further object is to provide a junction or connection between the unlike elements which will preserve an intimacy of contact thereof each with the other without the interposition of such matter as would tend by setting up a local action to diminish the efficiency of the battery.

A still further object is to employ elements and junctions therefor of a character to cause or result in increased efficiency of the battery, and a still further object is to provide a battery and its appurtenances which may be readily applied to an ordinary cook-stove or heater in a manner to utilize that heat which might otherwise not be used.

The invention consists in those novel features in the arrangement of the various elements, in the means of joining or connecting same, and in the appurtenances employed to increase the efficiency of the battery, hereinafter set forth and described, and more particularly pointed out in the claims hereto appended.

Referring to the drawings, Figure 1 is a perspective view of an ordinary type of domestic range, showing a section of the fire-pot and of my battery and its appurtenances attached thereto. Fig. 2 is a horizontal cross-section of one portion of the battery and its appurtenances, and Fig. 3 is a view of a single pair of detached elements with the coupling or connection for electrically connecting succeeding pairs of elements.

Like letters refer to like parts throughout the several views.

In the drawings, A indicates an ordinary cook-stove or range; B, the top plate thereof; C, the fire-grate, and D the flue-pipe. The fire-box is provided with brackets E, adjoining said grate C, which are designed to carry the fire-bricks.

In the practice of my invention I employ a block *a* of fire-clay or similar non-combustible material, which is non-conductive of electricity. This block *a* is subjected to the action of the fire contained in the fire-pot either directly or through a metallic facing to said pot, and preferably I mix a fibrous non-combustible agent, as asbestos, with the body of said block to increase the cohesive strength thereof. Embedded in said block *a* are a plurality of what may be termed "negative elements" *b* and "positive elements" *c* arranged in pairs, one end of each pair of which extends within said block to a point about one-half an inch from the exposed face thereof and the other end of which projects from said block for from two-thirds to three-quarters of the length of the elements beyond the rear face thereof. These elements *b* and *c* are arranged in a plurality of parallel rows, those in each row being preferably about one-quarter of an inch apart and the rows being about one-half an inch apart. This arrangement serves to not only transmit heat to the ends or joints to be heated of the elements embedded in said block, but also to insulate said joints from each other, which permits the coupling of the elements in series without setting up local action between adjoining pairs of elements.

I have found in practice that the best results are attained by making each element *b* of an alloy of antimony and zinc in the following proportions: six parts of antimony to four of zinc.

In joining the various elements *b* and *c* of each row it has been demonstrated that considerable internal resistance will be developed

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No. 824,684. Specification of Letters Patent. Patented June 26, 1906.

Application filed February 15, 1906. Serial No. 248,683.

To all whom it may concern:

Be it known that I, GEORGE H. COVE, a subject of the King of the United Kingdom of Great Britain, residing at Roxbury, in the county of Suffolk and State of Massachusetts, have invented certain new and useful Improvements in Thermo-Electric Batteries and Apparatus, of which the following is a specification, reference being had therein to the accompanying drawings, which form a part thereof.

The invention relates to thermo-electric batteries, and more particularly to the composition of the various elements and their arrangement with relation to the source of heat and each other. The underlying principles of batteries of this type are well-known in this art, and such will not, therefore, be referred to at length.

The object of this invention is to utilize these well-known principles in a manner to produce an external current capable of being employed advantageously in the useful arts.

A further object is to so arrange the various elements as to permit the subjection of one end or joint of each pair of elements to an intense constant heat, while permitting the other end or joint to be maintained at a relatively low temperature.

A still further object is to provide a junction or connection between the unlike elements which will preserve an intimacy of contact thereof each with the other without the interposition of such matter as would tend by setting up a local action to diminish the efficiency of the battery.

A still further object is to employ elements and junctions therefor of a character to cause or result in increased efficiency of the battery, and a still further object is to provide a battery and its appurtenances which may be readily applied to an ordinary cook-stove or heater in a manner to utilize that heat which might otherwise not be used.

The invention consists in those novel features in the arrangement of the various elements, in the means of joining or connecting same, and in the appurtenances employed to increase the efficiency of the battery, hereinafter set forth and described, and more particularly pointed out in the claims hereto appended.

Referring to the drawings, Figure 1 is a perspective view of an ordinary type of domestic range, showing a section of the fire-pot and of my battery and its appurtenances attached thereto. Fig. 2 is a horizontal cross-section of one portion of the battery and its appurtenances, and Fig. 3 is a view of a single pair of detached elements with the coupling or connection for electrically connecting succeeding pairs of elements.

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I have found in practice that the best results are attained by making each element *b* of an alloy of antimony and zinc in the following proportions: six parts of antimony to four of zinc.

In joining the various elements *b* and *c* of each row it has been demonstrated that considerable internal resistance will be developed elements is formed, means circulating air about the projecting ends of said elements, means whereby said blocks are subjected to continuous heat, a secondary battery and connections between the dissimilar terminal elements of said series and the opposite poles of said secondary battery.

2. A thermo-electric battery and appurtenances comprising a block of incombustible, non-conducting material, a plurality of pairs of elements each comprising respectively a connecting-strip having on opposite sides at each end of and integral therewith, a cup or cap, and a dissimilar metal element having one end thereof fitted into one of said cups or caps and in a similar cup or cap of an adjoining pair of elements whereby a series of such elements is formed, binding-wires about said cups or caps, one end of all said elements being embedded in said block, terminal wires leading from dissimilar elements of said series, and means whereby said block is subjected to continuous heat.

3. A thermo-electric battery and appurtenances comprising a block of incombustible, non-conductive material, a plurality of pairs of elements of dissimilar metals having one end of each joined to the other and embedded in said block, the outer end of each said element being joined to a dissimilar adjoining element whereby a series of such elements is formed, a housing or casing inclosing the projecting ends of said elements, an air-inlet to said casing or housing communicating with a source of cold-air supply, a discharge-pipe for said casing and means circulating air through said casing, said inlet and said discharge-pipe, means whereby said block is subjected to continuous heat, and terminal wires leading from dissimilar elements of said series.

4. A thermo-electric battery and appurtenances comprising a heater, a fire-pot and a flue therefor, a block of incombustible, non-conductive material disposed about said fire-pot, a plurality of pairs of elements of dissimilar metals having one end of each joined to the other and embedded in said block, the other end of each said element being joined to a dissimilar adjoining element whereby a series of such elements is formed, a casing or housing comprising two connecting passages one inclosing the projecting ends of said elements, an air-inlet in this passage communicating with a source of cooled air, a discharge establishing communication between the other passage and said flue, and terminals to two dissimilar elements of said series.

5. A thermo-electric battery and appurtenances comprising a block of incombustible, non-conductive material, a series of pairs of elements comprising a plurality of dissimilar metal elements, and a plurality of metal elements connecting said elements successively, said connecting elements all being dissimilar to said first-mentioned elements and to the next adjoining connecting element, means whereby said block is subjected to continuous heat and terminals leading from dissimilar elements of said series.

6. A thermo-electric battery and appurtenances comprising a block of incombustible, non-conductive material, a series of pairs of elements comprising a plurality of elements formed of an alloy of antimony and zinc, and a plurality of elements connecting said antimony and zinc elements, said elements connecting said first-mentioned elements being alternately of copper and of an alloy of nickel, copper and zinc.

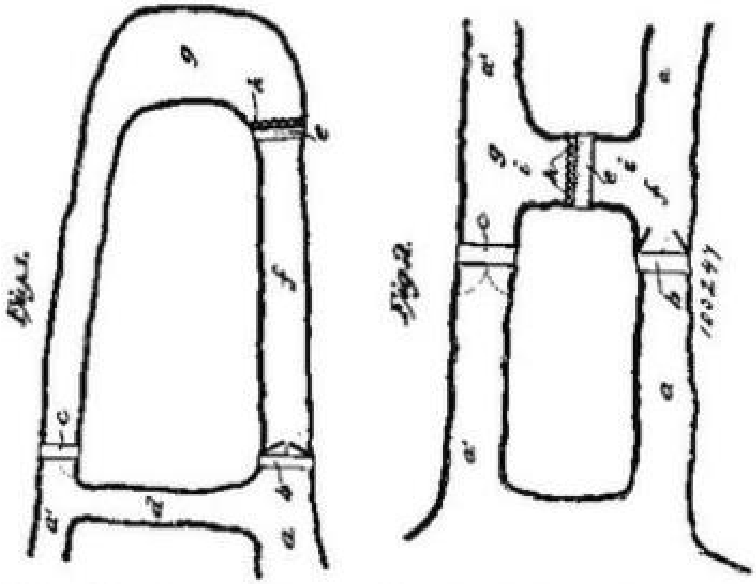
In witness whereof I have hereunto affixed my signature, this 9th day of February, 1905, in the presence of two witnesses.

GEORGE H. COVE

Witnesses:
ELI SHELDON,
JOSEPHINE MORAN.

George Cove tidal patent documentation

No. 100,247. Tide Power System.
Système de pouvoir de marée.



Walter Fred Cove, George H. Cove and Frank R. Kimball, Boston, Massachusetts, U.S.A. 31st July, 1906; 6 years. Filed 8th June, 1906. Receipt No. 136,694.

Claim.—1. In a tide water power system a dam fitted with gates whereby water may be supplied thereto or near flood tide, a tide water channel below said dam, a second dam, a turbine, turbines or other water wheel beyond said second dam, flumes or tubes passing through said second dam and leading to said turbine, turbines or wheels respectively, a discharge basin beyond said turbine of greater area than said reservoir, a third dam fitted with gates whereby water may be discharged from said basin at ebb tide, and a channel beyond said last-mentioned dam communicating with the sea.

2. In a tide water power system the combination of an upper and a lower dam disposed in a continuous channel, an intermediate dam whereby a reservoir and a discharge basin is formed in the channel between said first-mentioned dams, gates in said dams respectively whereby water may be stored in said reservoir and excluded from said basin at flood tide, and water may be discharged from said basin at ebb tide, water wheels arranged beyond said intermediate dam, and sluices or tubes passing through said intermediate dam and establishing communication between said reservoir and said wheels.

3. In a tide water power system the combination of an upper and a lower dam disposed at different points on the bend of a tide water stream and a channel connecting the channel of said stream at a point above said upper dam with a point below said lower dam whereby a continuous channel is formed, an intermediate dam whereby a reservoir and a discharge basin is formed in the channel between said first-mentioned dams, gates in said dams respectively whereby water may be stored in said reservoir and excluded from said basin at flood tide, and water may be discharged from said basin at ebb tide, water wheels arranged beyond said intermediate dam, and sluices or tubes passing through said intermediate dam and establishing communication between said reservoir and said wheels.