Electric cars

Personal view on expectations and reality

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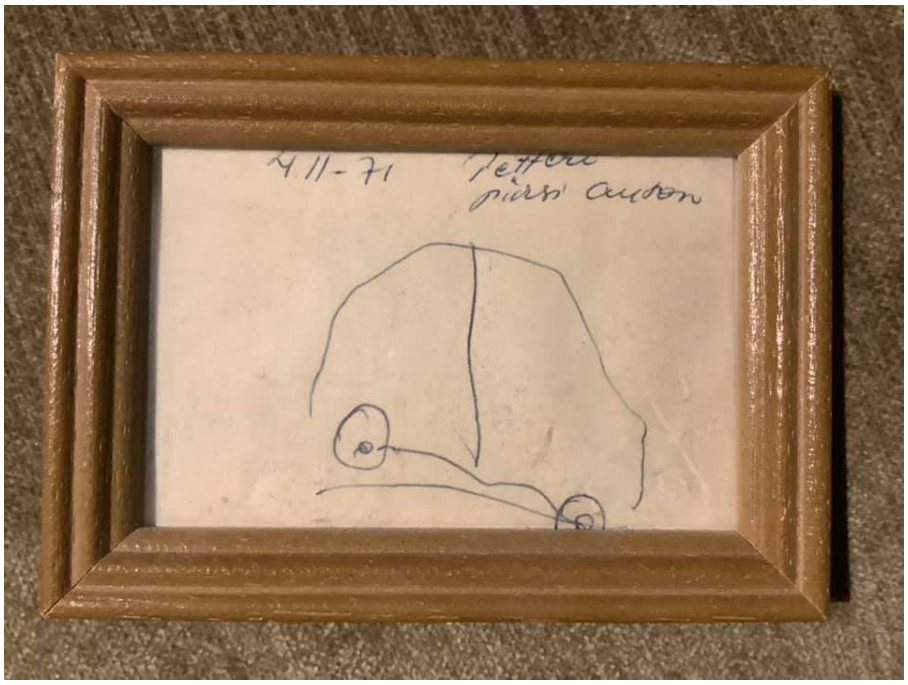

My car design from 1971 (note: this must be an electric car, there is no exhaust pipe)

1. Introduction

1.1 So, why this text?

The trigger for this text was the announcement from Lähitaksi, one of the major taxi companies in Finland, that they will favor electric and hybrid taxis when processing orders. This has caused some muttering between the car owners - naturally if you have just bought a diesel or gasoline powered car, this may make your situation worse. To ease the situation, they possibly could have given a warning 2-3 years beforehand. Maybe they did it and car owners didn't take it seriously, I don't know.[1]

I have had my own thoughts on electric cars during the years, but never managed to really process or write those down. Is it good or bad, pure laziness and lack of time? Anyway, it would have been interesting to see what I thought about it earlier (10-20 years ago) and how my thinking has chanded, if it has. Writing down things also helps to open the ideas in my mind because then I have to really think about what I say. So, I write here some random thoughts about e-cars and things around it as a scientist who is not working in any of the related areas but gives the absolute truth[2] about transportation, environment and everything.

This is now version 1.0 of the text. Things may change rapidly within a short time, so this is only a capture of the situation in the fall / winter of 2021-22 and this will be soon outdated. I may publish later an updated 1.x version or even a completely new 2.0 version if I have time. And if there is any use for that. It's possible that I don't have time and even more likely I have lost interest to update this. An early revision 0.1 was published in Facebook and Linkedin in the beginning of fall 2021.

1.2 Standard disclaimers

Some things to keep in mind while reading.

1) I'm talking here about small cars for personal use, not trucks, delivery cars or similar. I don't know much about those. Their requirements for daily use differ quite a lot from the normal family car usage. Maybe I'll come to those in the v2.0 of this document. Maybe.

2) I'm not a fanatic fan for e-cars, hydrogen cars, or any other solution per se. I'm not in position to affect to the possible EU-wide (or global) choice of the future way of powering

[1] I'd like to know if something like this has happened beforehand, but I don't have time or energy to try to find the anwer.
[2] 42

the cars. I can of course vote, which does not have any effect in practise ('sigh') on these decisions. I can just wait what will happen. My future decisions on our family transportation will be made based on *convenience* of moving with our restrictions in mind and *money* that we have to spend to do that. The transortation alternatives that I see at the moment are privately owned car, leased car (company car or private leasing), use of a jointly owned car, or public transportation (trains, buses, taxis etc.). The same considerations have been evaluated every time our car has been changed and so far the most viable solution has always been having an own or a company leased car. Fuel choice has changed between gasoline, diesel, and now the latest selection was a plug-in hybrid car.

However, I like to drive with electricity with my current plug-in hybrid, it's quiet and feels responsive to the gas pedal. Thus, it could be great to have an e-car. Why or why not? Most likely after ten years, there is no need to make that choice. These thoughts I will write down in the following text. If it sometimes sounds negative towards e-cars, keep in mind also my positive first feelings towards semi-e-cars.

3) All values here are some average values that I have picked. They do not represent the absolutely correct values, but they are "rough estimates" to give a hint, where we are now, what things cost, how much electricity we need for cars and so on. There may also be mistakes in calculations, but they are due to the sunspots and definitely not my fault.

4) This text is a mix of objective facts, estimates and subjective thinking. And this is *not* based on a scientific research.

2. Basic comparison between different cars

For many, a privately owned car is the only viable choice for moving around. There are various reasons behind this, for example personal physical limitations, family with different hobbies and transportation needs, work where you have to travel long distances and/or during unorthodox hours, living in the countryside or in a city without any or with a poor public transportation and so on. I'm not talking with anyone else's voice, but only with the experience I have. Also, in this text I consider ONLY the case when you select a car that will be solely used by you and your family.

Now, I go through some things that may affect the selection of the car, possibly during the next 10-15 years. After that, the available selection of possible traditionally powered cars will decrease dramatically as some car manufacturers have already decided to give up making gasoline or diesel powered cars after 2030. But for now, we have many things to consider when selecting the vehicle.

2.1 What people think when selecting the car?

There are at least three major things to consider when selecting the car: *environmental issues*, *convenience*, and *money*. Of course, the size of the needed car depends e.g. on the transportation needs etc.

Money guides many times that the selected car just fulfils the minimum transportation needs, at least in Finland where cars have traditionally been very expensive and gasoline damn expensive. The problem with this thinking is naturally that the car has been some sort of status symbol because they are so expensive, just like alcohol has become the king because it has been forced to be a scarse resource with sales limitations and taxes. The more you try to limit people, the more people want the limited subject. Unfortunately, many politicians just cannot see this. Well, now I'm on a side track, I have to back to the original topic.

Convenience is a factor that you cannot avoid. People must move and we have the freedom to travel if we want. At least for now. Unfortunately, there are very limited possibilities to do that in Finland without the car. Buses and trains provide only a very limited set of connections, and unless your starting position and the destination are very close to some bus line or train station, this option becomes very quickly a bad option. Flying? Makes sense only very seldom. If you have to take a very expensive taxi on both ends of your travel, *money* becomes again the problem. Trains and buses have become cheaper once we got rid of the socialism that controlled that business, but when you add some 2 x 50e to the ticket prices because of the needed taxi, you lose again a lot. And taxis can never be cheap in Finland because of expensive cars, expensive fuel and highly regulated salaries. So, the consumer loses again and car sellers (and government) get the profit.

It's also funny that some people are sitting in the middle of the road blocking traffic and fighting against private cars because, hmm.., envy. For them it is possibly easy to use the public transportation, thus it is also easy to demand that everyone else must get rid of their cars. The problem is that they represent only a very small fraction of all people in Finland and they want to make all suffer. The funny thing is also that they are talking about CO2 and environment, but when the majority of cars are e-cars, they will fight against them (*this was my earlier prediction, which already became the truth accrodingly some Green party members in Twitter, I could not find the tweet any more)*. So, from the beginning, they are talking bullshit with their reasoning, simply, they are just lying. I just wonder, how many of these young people will have their first car in five to ten years when they have their own kids and notice that you just cannot manage without the car.

With just the public transportation option, you are not necessarly willing to come to the city center if you have alternative places to make shopping, i.e. the city center shops will suffer from that. I'm not saying that this is a bad thing except for the shop owners. And possibly the reduced services may affect the attractivenes of the center area. Who would like to be in an empty center?

Environmental issues is a thing that many people are actually thinking when buying a car. However, *money* and *convenience* are still the dominating things when the selection is made. E-cars are expensive compared to their transportation capabilities and charging at this point is for most people far too inconvenient or even impossible. But next we can go to the interesting part, calculations.

2.2 Filling up the tank

I mostly talk here about standard gasoline and diesel cars versus electric cars. I know, there are other alternatives from the old wood gasifiers to the hydrogen cars. But to keep this simple, I'll concentrate only on these three options. Hydgrogen cars are a very interesting alternative, but I have to dig into those maybe later. At the moment, they seem not to be a viable solution in Finland, at least in a short term.

Electric cars: are they convenient enough to operate? Convenience, or the lack of it, can be the limiting factor in people's behaviour when selecting the (e-)car.

First some basic assumptions with "filling tank" / "charging battery":

- Traditional car, consumption is ~ 7 liters / 100 km
- Filling tank at a gas station: 7 liters ~14 seconds (haven't measured)
- Electric car, consumption is ~20 kWh / 100 km (average car)

First: how much charging power we should have to match the required time to fill the tank for 100 km? Simple calcuation: P = E / t = 20 kWh / 14 s = 20 kWh / 0.0039 h = 5.14 MW

5.14 MW charging? That is sci-fi still at the moment and far from the current maximum charging capability that many cars have, which is ~155 kW (there are exceptions such as Porsche Taycan 270 kW which is still far from the 5.14 MW. My plug-in hybrid can do 3.7 kW, wow!).

I suppose (correct me if I'm wrong), that such 155 kW stations are not common yet. Quick non-scientific check with latauskartta.fi reveals that there are some, even to 300 kW, but not that many in Finland. Most likely more will come withing few years..

Second: how long does the filling of the tank / charging battery take for, lets say, 500 km driving?

- Filling tank with gasoline would take 70 seconds, so the time spent at the pump is roughly three minutes. One pump would serve 20 customers per hour.
- With 155 kW e-car, charging would take t = E / P = 100 kWh / 155 kW = 39 minutes, BUMMER! If you are really quick, 40 min would be enough. One charging station can serve 1,5 customers per hour.

For an average person, this would mean time for some burger meal or longish coffee break which possibly could give some entertainment during the charging. But I wouldn't like it. What if all charging points are reserved? Waiting time may become veeeeeery long and if you are running out of electricity, you don't have any other possibility than wait.

For the gas station, these calculations would mean currently 14 charging points when compared to 1 gasoline pump (four pumps = 56 charging points and so on...), requiring much more space and investments which I cannot really calculate as I don't have the

required information neither for charging points nor for gasoline pumps, underground tanks, and related stuff. There are strict environment protection directives form those facilities. Charging points would require effective power supply to the station. I don't now currently what the stations currently have and what are the possibilities to increase the capacity when needed.

2.3 Other considerations

An e-car has the luxury to charge also at home if you have a charging station. This is obviously something that you cannot have with a traditional car; having a gasoline storage at home would be insane. On the other hand, vacation resorts could have charging points for customers, probably they already have. Considering trips in Finland, from Helsinki to Lapland, you most likely need to stop once or twice to charge / fill the tank [3]. It seems that the main inconvenience with e-cars are the longer trips or when you have to keep the car warm without the charging possibility, e.g. taxis. In those cases, the charging speed creates the bottleneck.

But what is really the problem, or is there one? With my driving, I could do almost everything with a home charger. My maximum distance for a long time has been like 300 km one way, in which case I would need to charge maybe once during a trip. I'm also sure the new charging points will emerge as time passes, mostly in natural places where people stop or keep their cars. .

Another thing is the fuel consumption and needed electricity during winter time. Everyone knows two things:

1. With a gasoline and diesel cars on short distances, the consumption is high. Long distances compensate the consumption a little.
2. With batteries the driving speed and temperature affects a lot to the driving distance.

I don't have any information to make even a rough comparsion between these two cases. Maybe I should try to google a bit, but meh...

2.4 Summarizing the situation

If I had a home charging station and an e-car with long enough range, say 600-700 km, that would be mostly ok. However, in many condominiums it is not possible to get home charging stations. I assume that they will come more common in the future, but they usually require investment to the power grid at the parking lot. Currently in Finland they are mostly

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[3] I know, some cars that can do > 1000 km without stopping and some people can even drive 2000 km with that car although no-one else can (source e.g. suomi24.fi chats). My old small diesel VW did over 1000 km in optimal conditions. But let's talk about average cars and people without superhuman skills.

suited to the 2kW heaters per car. In twenty years the situation will change as most of the house owners have an e-car and there is no point resisting the investment.

We have to note also that those announced ranges that car manufacturers provide are in optimal conditions, not in those that we have typically in Finland. This same goes with gasoline/diesel cars also, but as mentioned, there are more (and faster) gas stations so it does not matter so much, only from the money perspective. But how much is the effective range actually? It is easy to optimize the tank filling with gasoline cars: it's not too long distances between two stations (except in the northern Finland) so you can safely drive the tank almost empty, which I sometimes do also. With e-car, I assume that I wouldn't dare to drive so that there is less than 50km estimated distance left.

So, the requirement is also that if I need to stop somewhere for charging, I don't want to use 1-2 hours at some McDonald's or shopping center, but I want to charge in ten minutes. This is especially important if the range of the car is shorter, e.g. less than 500 km. If the charging time is longer than that, it is frustrating. In ten minutes I can take a leak, but I hate if I have to wait more than that. Yeah, yeah, you can have a longer break and eat and... blah blah blah. I haven't done that earlier and certainly I'm not going to start doing that.

We can now take an example from the existing e-cars, the Hyundai Kona (just a random pick). The CCS fast charging takes from 10% battery to 80% some 47 minutes, which for many people can be ok. I don't like that, it's too long. One problem may also pop up when you drive to the charging station and there is all reserved. Do you wait 1-2 hours before you get your 1 hour slot? That may easily happen. If you think it is ok, then it's fine, but for me that is really a no-no!

On the other hand, if we had fast charging stations, i.e. nearly comparable timewise to the current gas stations, then I wouldn't need a home charger at all. Why would I need if I can go and charge my car in ten minutes once a week similarly as filling up the tank now?

It seems that the current situation is still really, really unclear. We have something that is ok for some people but for the mainstream usage neither the infrastructure nor the cars are ready yet.

3. Other related considerations

This section goes into more dark area and is full of ghosts and goblins. There are lots of alternatives, and you cannot have one correct solution or correct answer to any questions we have in the area. In any case, you end up with endless discussion on different ways of thinking which produces basically zero result with a huge amount of energy spent to useless arguing between the people involved in the discussion. Of ten people discussing, usually there is one who understands even something on the topic. You may check these e.g. from Twitter with suitable hashtags.

3.1 Requirements for the infrastructure in different cases

The starting point for the infrastructure discussion is the amount of cars and the distance that we drive with them. I'll dig up some statistics from Finland and use that for making the estimations for different alternatives.

3.1.1 Gasoline / Diesel

This infrastructure has been well establised during the past hundred years. It exists and it's not going away. Well some changes have happened, for example the number of gas stations has decreased, especially the smaller ones in the countryside have been closed down. They are just not needed anymore. Nowadays mega-hyper stations with all other entertainment and restaurant options are dominating outside the city centers.

3.1.2 Electricity

While the electricity is considered to come from the wall, this is not the case. It must be genereted somehow and delivered to the wall sockets. An electric car needs quite a lot energy to move and when we have millions of those cars, they need a huge amount of energy. The supply of electricity to the charging stations requires infrastructure as you cannot really produce the electricity from the wind or sun locally at the station, but let's give it also a thought. Here I must say that I have no idea what kind of systems the current gasoline stations have for their electric supply, but I assume that it is not enough when we have more electric cars that need really fast charging.

3.1.3 Hydrogen

Obviously there are not really refuelling stations in Finland at the moment. I read an article in Tekniikan Maailma (or it may have beena also some other magazine) that mentioned that there are really no refueling possibilities in Finland. At that time there was one (1) station. Things are different already in Estonia. This option would require building this infrastructure. It would be nice if we could produce hydrogen locally in the refuelling stations but this requires electricity. I have no clue about the system that would be needed for that, so this is just a thought.

3.2 Environmental effect with the car itself

There are many different calculations about environmental effects of different types of cars, both from the manufacturing and usage perspectives. With so many variables and different ways to calculate things, anyone can adjust the parameters so that result matches his/her opinion. So, all information can be considered to be biased.

3.2.1 Batteries

It's quite boring when, especially the yellow press, is taking some research results and advertising that "We have now a great battery solution that solves everything!" etc., but no mention that it works maybe on a small 1.5 V battery and possibly in a car battery in 15-30 years if ever. Not saying that the mass production can start maybe in 50 years. Maybe.

Anyway, this is "the thing" that is always used to critique electric cars. Obviously there may be a problem when manufacturing batteries for e-cars, especially with certain metals that are mined in Africa and South America. As usual, in the Internet, the articles are only whining how bad situation is. I haven't really read any good article that explains without fanaticism what the situation really is. But, please, provide me some peer-reviewed and published research on that topic.

I'm pretty sure that the development of batteries will take big leaps in the future, which *may* decrease the described problem with metals. I don't know. And to be honest, I don't care - or lets put it so that I don't think about that much as that is something that I cannot affect at all. The decisions are made by others and that is the right way to go. Don't ask stupid guys like me.

At some point in 1980's(?), there was a debate about catalysators in gasoline cars, how much rare metals are needed in those, how to get it and how much this affects people in Africa. Sounds familiar? We have the same debate going on now with the batteries.

3.2.2 Other manufacturing and maintenance considerations

But what is the actual difference when manufacturing a traditional car vs. e-car? In general, e-car technology is simpler, does it mean that it is more enviromental friendly if we don't think about batteries? I have no idea. There are so many headlines in the news that are against e-cars from environmental perspective as a whole, but I think that there are people behind these articles that just will lose their jobs when the oil business suffers. Or then they just have the habit of whining, no matter of the topic.

I have understood that e-cars are quite maintenance free. Of course, some parts are similar, e.g. suspension requires similar maintenance in both types of cars. But there is no need for oil change, reducing the need for it. In addition of course to the amount of oil that is needed for producing gasoline. I don't take the service price differences into account in the example calculations, as I don't know how much they are. They vary also a lot between different manufacturers and even models.

3.2.3 Quickly replaceble batteries?

What if we the car batteries could be quickly replaced at the charging station? This has been investigated, but there seems no to be any viable large scale solution yet. Might be a good option in the future. Most likely these would be separate companies providing the service and

the batteries should be standardized somehow, not all car models can have different batteries, otherwise the battery changing station would be full of different kinds of batteries. Another problem is that this would currently require manual work, could this be automated somehow?

3.3 Some example calculations

3.3.1 Cost of driving

Let's compare first two as similar cars as possible, one diesel and one e-car. The problem is that there are not some many "similar" cars, the trend seems to be that e-cars are specially designed to be e-cars, thus the sizes and accessories can be very different. The power of the engines varies and also the prices are not comparable always. I picked the two most similar cars that I quickly found and I didn't go through all the detailed differences in them. The purpose was anyway to give some rought estimates.

I didn't calculate the possible home charging station (~1000e) because that can be used more than four years, it can be provided by the housing company, or then you just do not need it. The assumption is that you drive 2000 km/month. To make more detailed calculations, change the values to match your driving style. The values used here are directly from the Hyunday brochures [4][5]. Interest is inlcluded as you pay it always somehow: even if you have cash for buying the car, you could easily invest it somehow so I assume this also as a cost (lost profit).

The diesel/electricity for 2000km/month has price assumptions that are valid now, but not in the future.

Diesel: 20 * 7,4 l/100km * 1,70€/l = 251,60 €

Electricity: 20 * 14,7 kWh/100km * 0,15 €/kWh = 44,10 €

[4] https://www.hyundai.fi/wp-content/uploads/2021/09/Hyundai_KONA_Electric_hinnasto_10-2021_01.09.2021_autoveron_poisto_1.10.2021.pdf

[5] https://www.hyundai.fi/wp-content/uploads/2021/12/hyundai_kona_hinnasto_12-2021_01.12.2021.pdf

Hyundai Kona "Style"	1,6 GDI, 4WD, 198 hp	Electric 204 hp
Price	35390€	46186€ [6]
~ Interest for 4 years 2%	2832€	3696€
Price left after 4 years	20600€	26900€
Total variable costs	**17622€**	**22982€**
total gas/electric cost, 2 years	12076,80	2116,80€
TOTAL	**29698,80€**	**25098,80€**

I'm leaving out now insurance, tyres, maintenance as I assume that they are quite similar with both cars. I may be wrong here, as usual. Anyway, the total variable cost DOES NOT include those so these are not comparable for example when you calculate costs between your own car and the public transportation. This example is ONLY for comparing these two car models.

3.3.2 Additional electricity needed in Finland

At the end of 2020, we had 3 632 851 passenger cars in Finland of which 2 773 768 were actually in use [7]. In 2019, the driving distance with all passenger cars in Finland was 40 718 million km [8]. This means roughly 14 700 km per car (yeah, I know, different years, but I guess the figures are quite similar, corona probably somewhat changed the situation in 2020, but that's temporary). What if we replace all cars in Finland with e-cars? There is definitely a huge need for electricity after that. It is safe to say that the Kona's 14.7 kWh/100km is far, far from the actual truth, so I calculate here again with 20kWh So, assuming that we drive like earlier, the needed electricity is:

40 718 million kilometers => 40 718 000 000 / 100 * 20 kWh/100km = 8.14 * 10^9 kWh = 8.14 TWh.

Now we can compare this to the energy consumption in Finland during 2020 which was 81 TWh [9]. Thus, e-cars would create a roughly 10% increase in the needed electricity in Finland.

[6] The price is without car tax, this still depends on the goverment decision. If not approved, the tax will be added and must be paid later.
[7] https://www.stat.fi/til/mkan/2020/mkan_2020_2021-02-26_fi.pdf
[8] https://www.stat.fi/til/tiet/2019/tiet_2019_2020-04-15_tie_001_fi.html
[9] https://www.stat.fi/til/ehk/2020/04/ehk_2020_04_2021-04-16_tie_001_fi.html

Produced electricity in Olkiluoto 1 and 2 combined during 2019 was 14 751 GWh [10], which is close to the maximum of the new Olkiluoto 3 nuclear power plant. So, the e-cars would need at least one new nuclear power plant (of these old ones).

The problem is that the cars are not charged evenly throughout the year, but there are peaks e.g. around some vacation times, such as midsummer and christmas. It's hard but not impossible to create a charging environment, e.g. for home chargers, where the pricing would be heavily dependent on the load on the power grid which would force people to think when they charge making the load for the grid more even. But this is not always possible, e.g. if 500.000 cars are driving from home to "somewhere else" at the same time during christmas, they can charge at home during the past week depending on the other usage of the car, but when they are charging for return trip, this will happen during one or two days. In this case, one nuclear power plant would not be enough. If we had 10.000 e-cars charging at the same time with 155 kW chargers, this would mean momentarily 155 kW * 10.000 = 1,5 GW (which corresponds nicely to the maximum power of Olkiluoto 3's 1,6GW [11]).

It seems that the maximum battery capacity is now a little bit over 100 kWh, so full charge would take something like 40 minutes. During three days, we have (72 * 60)min / 40min = 108 "slots". Putting 100 000 cars evenly to these slots would give 926 cars per slot, that would mean 155kW * 926 = 143,53 MW and we suddenly don't necessarily need another nuclear power plant for this purpose. This is roughly 16% of the capacity provided by OL1 or OL2 powerplant. However, to get this best result, we need a very clever charging system which could distribute the charging evenly. There must be some possibility to give preferences to the car charging system and they must be able to communicate with the network for optimizing charging. There are many ongoing projects around this, but I'm not familiar with those.

3.3.3 Green power generated locally?

One always interesting thing is if charging can be done using solar power in the charging stations? How to store the electricity provided by the solar cells? Is there a way to build huge (I mean in practise huge!) batteries to store the electricity to support quick simultaneous charging?

Example solar panel today: roughly 200W/m2. 10m2 = 2000W = 2kW. With my car, I would need nearly 20m2 solar panels, to provide the 3,7 kW power for charging. 155kW charging would need roughly 840 m2 solar panels, i.e. 30m X 30m area. When it is sunny. How often this happens in Finland when needed? The problem is again, can we store the provided electricity and how much we lose when storing it in a huge battery and then charging the car from that battery?

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[10] https://ar2019.epv.fi/tilinpaatos/hallituksen-toimintakertomus/

[11] https://www.tvo.fi/tuotanto/laitosyksikot/ol3/rakennejateknisettiedot.html

4. Summary

So, this document was just written for fun and to clarify my own thoughts. It seems that there are lots of different things to consider at this point both for private persons when selecting cars and for our current and future goverments to figure out how to produce, import or steal the needed electricity. This will be a tough thing especially for the occasional consumption peaks that will come when the country is filled with e-cars.

Everyone has different weights for the things that I mentioned (or forgot to mention), so it is pretty sure that there is no solution that fits for all. There has never been such a solution and there will never be.

When we have a great share of the cars electric, it seems that a smart charging system is definitely needed for balancing the system and to avoid any shortage in electricity and/or a energy storing system with huge "batteries". I'm not familiar with the ongoing projects where these kinds of optimization systems are designed, but I bet there are many of them. Just use Google. It would be interesting to know (I don't have time now to figure it out), how the planned systems work, but if it is only on price of the electricity, it is boring. Also, we have to take into account that the same electricity is used for other purposes, so just raising the price is not necessarily a viable solution at the end. Without an intelligent charging system, it will be impossible to manage the whole electric grid.