

3-phase charging for the Model S in Europe

TESLA



Tesla Motors
Elon Musk
3500 Deer Creek
Palo Alto, CA 94304
United States

Middelburg, The Netherlands, October 27rd 2011

SUBJECT: 3-Phase Charging Support For The Model S

Dear Mr. Musk,

For any electric car, including the Model S, timely charging is one of the biggest issues the driver faces. Point in fact; the biggest feature the Roadster is missing is 3-phase charging. Europe's grid is built on 3-phase and is everywhere, but the Roadster can't take advantage of it!

To keep the phases in balance, Europe is limited to 32A maximum per phase. However, the availability of 32A outlets is very limited; 16A (single and 3-phase) is much more common and more widely available. Practically speaking, this means one might be able to charge an electric car with 32A, but most of the time one will only be able to charge at 16A.

Internal 3-Phase Charging for the Model S is essential for European customers because:

- 1. Almost every European home has a 3-Phase power supply.*
- 2. In Europe, you can't draw more than 7.3kW (32A) on a single phase, so charging a Model S fully over night is not possible on one phase .*
- 3. Most public charging stations in Europe are 3-Phase charging stations*
- 4. In Europe more customers will have to use public charging stations, because less people have a garage of their own .*
- 5. We expect a rather slow roll out of Tesla 90kW DC-chargers along the European highways .*

“Will the Model S support 3-phase charging?”

I've wanted to ask this question and I got my chance at the October 1st event at the Fremont factory. First, I have to say, the Model S beta event at the factory was a great experience. Seeing the Model S for the first time and driving in it was something I've been waiting for a long time. It really was worth the flight from the Netherlands!

After my test drive, I had the opportunity to ask the Tesla staff if the Model S would support 3-phase charging. I was very disappointed to hear the Model S would not support 3-phase charging, instead there will be a DC charger which draws its power from a 3-phase 400V source and feeds that into the car, but the car will not be able to utilize the 3-phases without an external (DC) charger.

Having garage space or a private driveway is a luxury in Europe (small and old city centers). That means that a lot of charging will be done at public chargers. Fortunately, Europe is doing well with laying out public charging stations.

The majority of these chargers use the IEC62192-2-2 (aka “Mennekes”) connector for charging. 90% of these chargers deliver 3x16A (11kW), but others, like those from RWE¹ in Germany even deliver 3x32A (22kW). The online map² of RWE shows a great number of RWE stations throughout Germany and the rest of Europe.

In the Netherlands the majority of the public charging stations is installed by E-Laad, all those charging stations deliver 3x16A of power. The E-Laad map³ currently shows 559 of

these chargers throughout the Netherlands, all able to deliver 11kW of power.

The goal of E-Laad⁵ is to have 10,000 of these chargers installed in the Netherlands. In other countries various incentives are being started as well.

Denmark for example, is planning to install 2,000 public 3-phase (3x16A) charging stations next year. France (With Paris in the spotlight) is also setting up public charging stations, all equipped with 3-phase power.

These are just the public available charging stations, but 3-phase power is everywhere in Europe! Farmers, (small) office buildings, restaurants, markets and hotels, they all have either a 3x16A or a 3x32A (CEE Red, IEC 60309) outlet available.

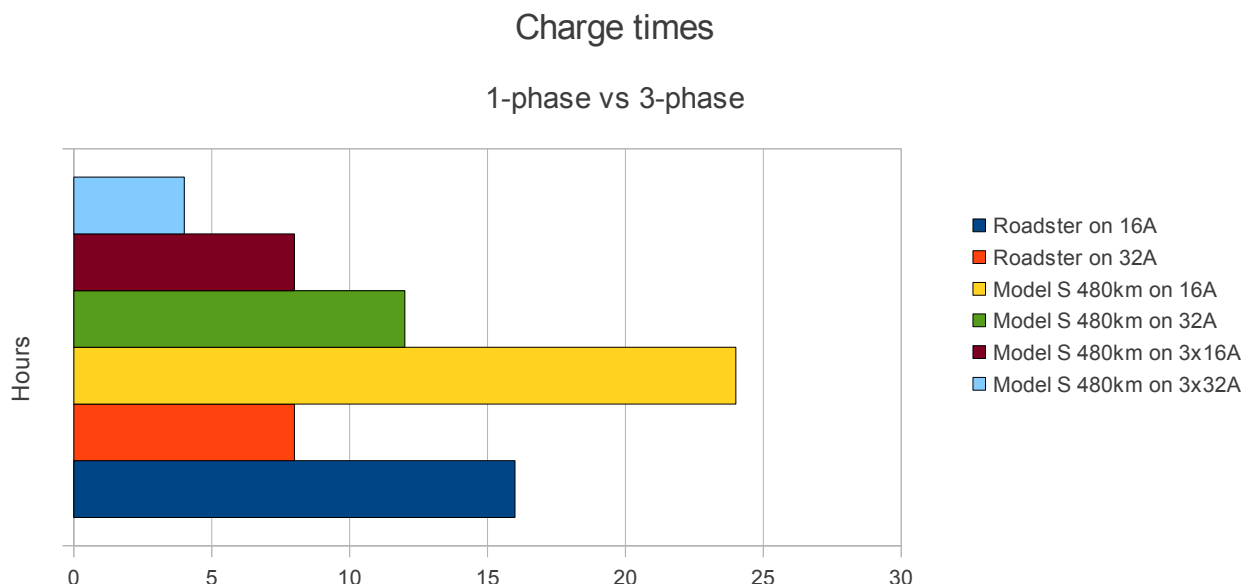
Not being able to utilize that available power will limit the daily use of a Model S, even with the biggest battery. The reason I was given at the factory event was the Model S doesn't have to be charged as often with the biggest battery, but I believe that line of reasoning is wrong for multiple reasons:

1. Not all customers will purchase the larger 480km/85kWh battery pack.
2. When the battery nears 0% SoC, it will take a long time to charge on single phase, thus limiting the use of the car.
3. The customer shouldn't be limited how far they are able drive the Model S, one might take the Model S on a road trip and want to do overnight charging at a hotel, motel or at friends.

Another thing that should not be forgotten is that the highway speeds in Europe are typically 120km/h or 130km/h (not mentioning the German Autobahn).

Basing my data on a blogpost⁴ from Tesla about the Roadsters range, driving at 130km/h will consume about 240Wh/km. That is based on Roadster data, without HVAC, radio or other energy consumers turned on. With the 85kWh battery that will give a range of 354km, but in the real world this will be somewhere around 300km.

I've set out the various charging times in a chart to show the difference in charge times:



The data on this chart is based on 230V with no losses during charging. All the energy drawn from the grid goes into the battery with a 100% efficiency. For the Roadster I've used 53kWh for the battery capacity, for the Model S, 85kWh. In practice, it will result in even longer charging times than displayed.

Even with a 32A charge, it will still take a 15 hour charge from fully depleted to a 100% SoC.

Arriving home (or somewhere else!) later in the evening with a near empty battery and leaving in the morning with a ~90% SOC is not possible with 1-phase charging.

This might not be seen as a realistic scenario. That might have been true for the Roadster because of its limited passenger and cargo area, but I think it is realistic for the Model S. People will use the Model S for all kinds of trips, business or pleasure. Driving 400km to their destination, charge overnight at a hotel and continue their journey the next day.

High power (90kW) DC chargers could resolve this, but their availability will be limited and I think it will stay that way. People will take routes where DC chargers are not available. An overnight charge is also much more convenient than a DC charge. Why wait 45 min. at a DC charger when the car could have charged overnight?

Besides overnight 3-phase power charging, there are so many other scenarios where one could use a 3-phase charge to fill up rather quickly. Ferry's to the UK offer 3-phase 32A charging on board. A 2-hour ferry to the UK from France would add about 40kWh, enough to continue one's journey.

For my work, I have to go to Amsterdam regularly, this is a 220km trip (remember our highway speeds). I leave in the morning and I'll be in Amsterdam for about 6 hours before driving back home. The 11kW charging in Amsterdam would have given me a near 100% SoC to drive back home with all the comfort I want.

DC and AC charging also don't mutually exclude each other; they will co-exist together and fulfill charging needs of drivers. 3-phase power is widely available. Why not take advantage of that?

I can't emphasize this enough: Europeans don't simply want 3-phase charging support for the Model S; they *need* 3-phase support!

I would like to compliment the whole Tesla Motors team for doing such a great job! Driving the Roadster is a great experience and after seeing the Model S this experience can only get better.

After being made aware of European's charging needs, I am confident Tesla will find a way to implement 3-phase charging support for the European delivered Model S. Whether it's a mobile/portable 3-phase to DC charger, 3 separate 10kW chargers inside the Model S or something completely different, that is up to Tesla.

Enclosed with this letter are endorsements supporting 3-phase charging. I choose to do this the "old" paper way to show Tesla that I (and the endorsers) are serious about this topic and want Tesla to take our recommendations into consideration.

Feedback can be sent through a more modern channel like e-mail.

Yours sincerely,

Wido den Hollander
Londensekaai 1
4331 JG Middelburg
The Netherlands

E-Mail: wido@widodh.nl
Telephone: +31 118 700 212

Sources

1. <http://www.rwe-mobility.com/web/cms/en/517314/rwemobility/products-services/smart-station/>
2. <http://www.rwe-mobility.com/web/cms/en/240690/rwemobility/charging-infrastructure/charging-infrastructure/>
3. <http://www.e-laad.nl/standaardisatie-stekkernorm-type-02-modus-03/98-wat-zijn-de-specificaties-van-de-oplaadpunten-van-stichting-e-laadnl>
4. <http://www.teslamotors.com/blog/roadster-efficiency-and-range>
5. <http://www.e-laad.nl/over-ons>

Attachments / additional information

On the next pages

3-phase charging stations in the Netherlands

E-Laad installs charging stations nation-wide in the Netherlands. It is a co-operation between various dutch energy corporations. Their goal is to install 10.000 charging stations in the country.

Total number (11-10-2011): 559

Available power: 2x11kW

Connector: 2x Type 2 (IEC 62196-2-2)

Source: <http://www.e-laad.nl/>



3-phase charging stations in Amsterdam

All charging stations in Amsterdam are installed by "Amsterdam Elektrisch", separate from E-Laad (which is nation wide).

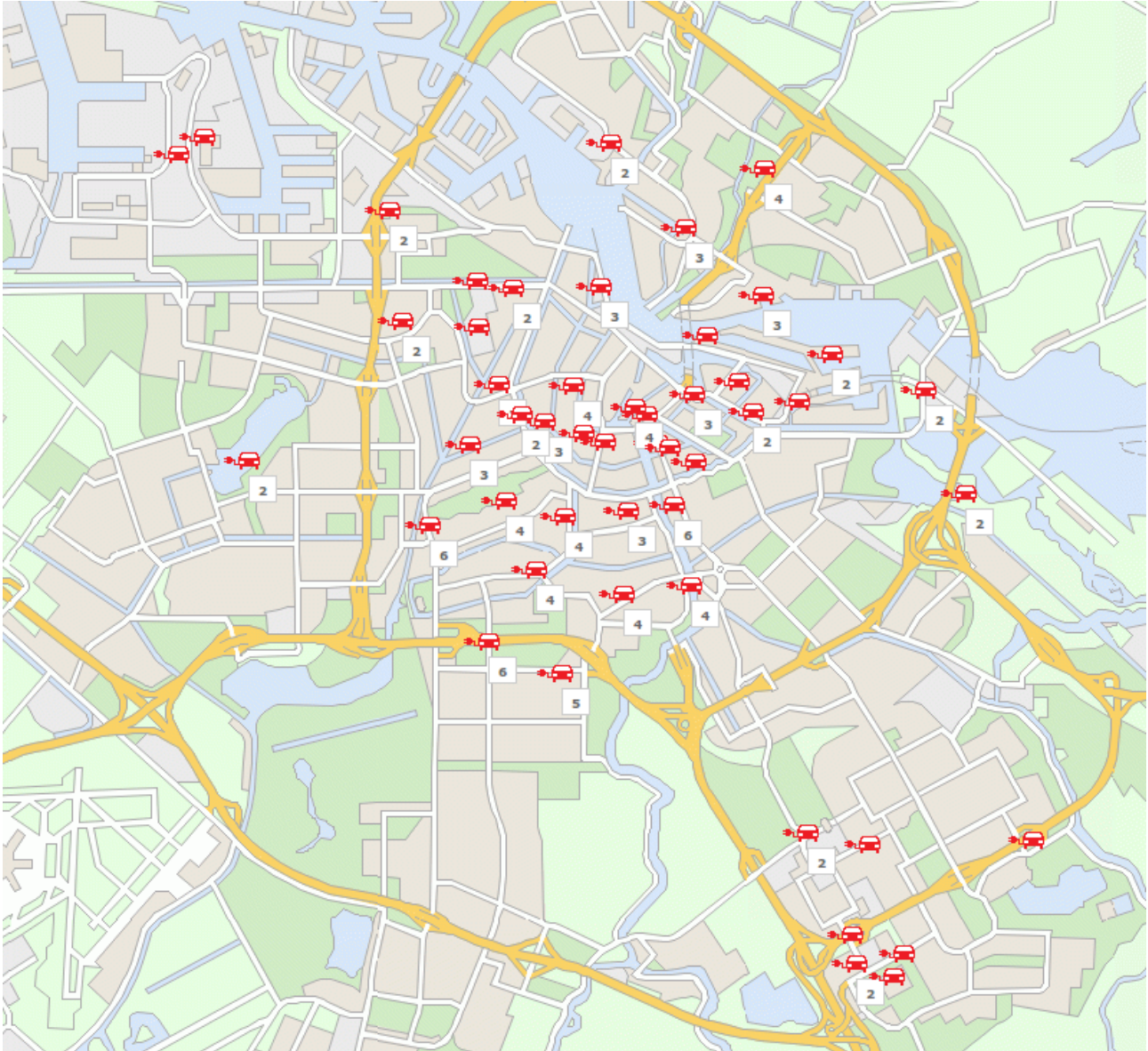
Amsterdam has the fastest growing number of charging stations in the Netherlands. Weekly they are installing about **5** new charging stations. Amsterdam is targeting towards a thousand charging stations in the city by the end of 2012.

Total number (28-09-2011): 250

Available power: 2x11kW

Connector: 2x Type 2 (IEC 62196-2-2)

Source: <http://www.opdekaart.amsterdam.nl/oplaadpunten>



Note: The map doesn't show all charging stations! The number underneath a car icon shows the additional charging stations in the near vicinity.

3-phase charging stations in Germany

In Germany charging stations are being installed by E.On, RWE, Vattenfall and Wien Energie. Lemnet.org gives a good overview of these locations.

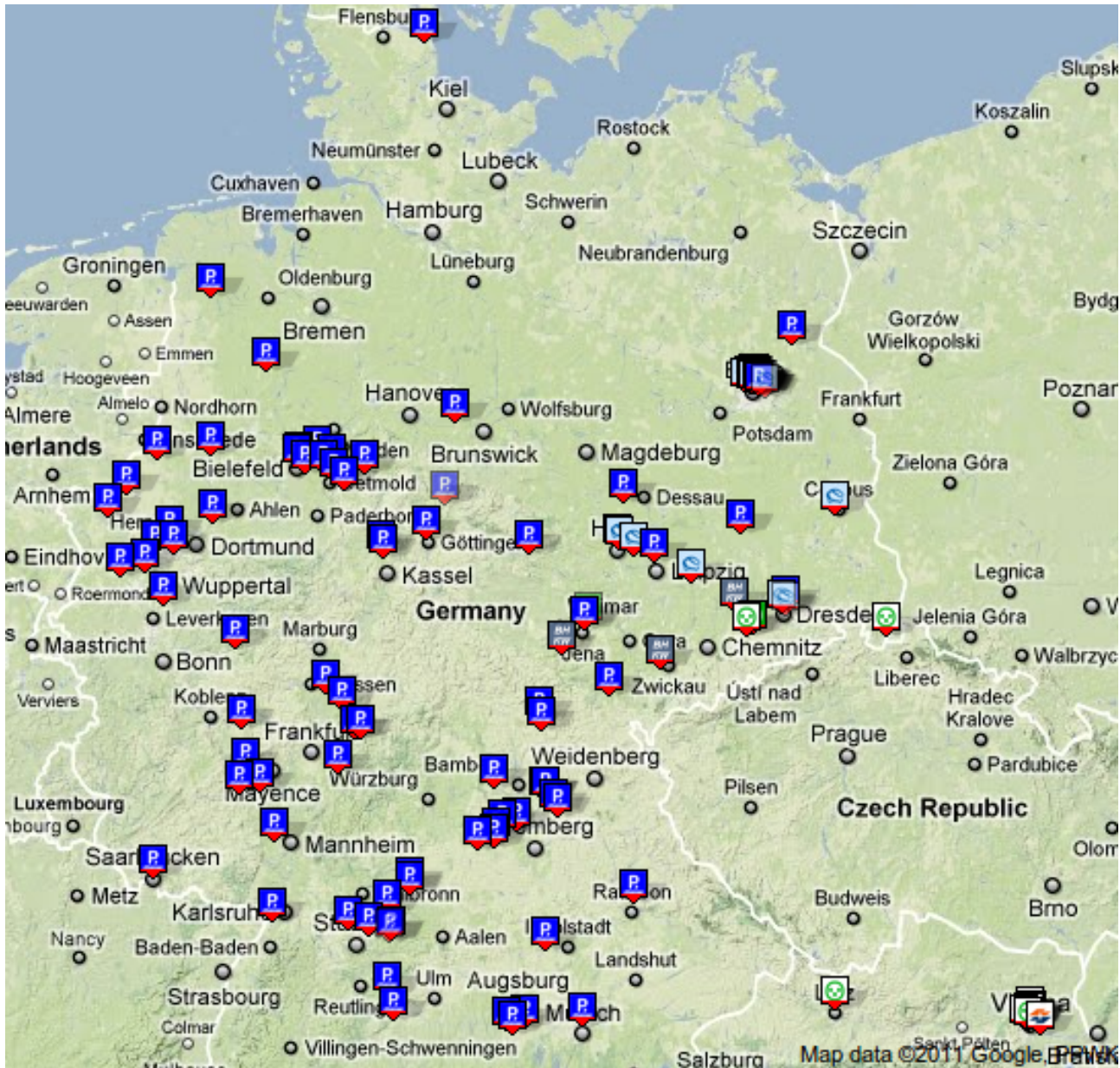
The map below only shows the 3-phase charging stations in Germany (and a bit over the border).

Total number (28-09-2011): **902** (See the note below the map!)

Available power: 2x11kW or 2x22kW

Connector: 2x Type 2 (IEC 62196-2-2)

Source: <http://www.lemnet.org/>



Places within the map area: 902 entries, 150 of them shown | [Show list of locations](#)

3-phase charging stations in Paris

Paris is also working hard on installing charging stations for electric vehicles. Just like Amsterdam they have emission reduction goals.

Parking for EV's is free in a lot of areas.

Total number (14-10-2011): **113**

Source: <http://www.paris.fr/>



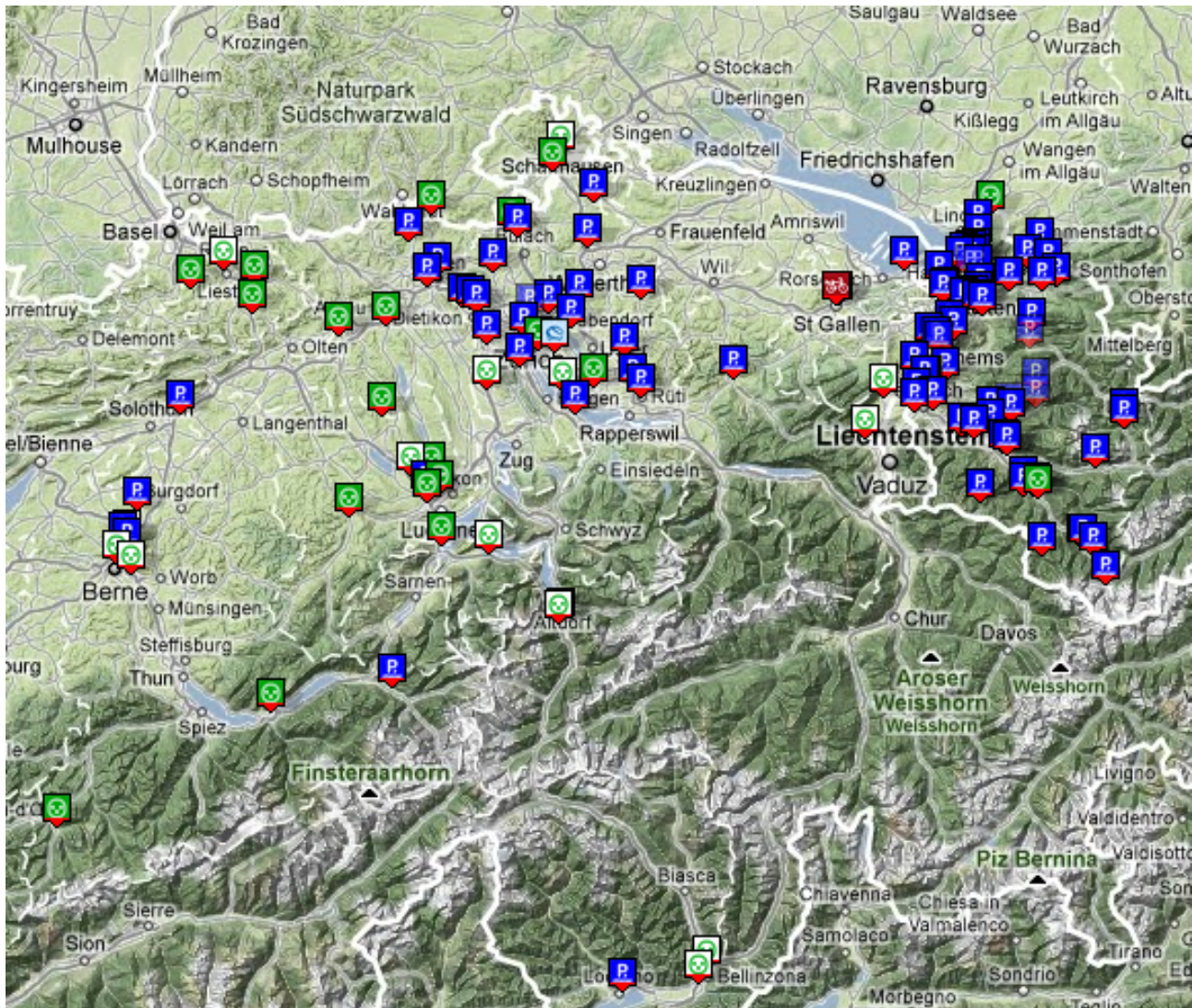
3-phase charging stations in Swiss/Austria

Total number (14-10-2011): **202** (See the note below the map!)

Available power: 2x11kW

Connector: 2x Type 2 (IEC 62196-2-2)

Source: <http://www.lemnet.org/>



Places within the map area: 202 entries, 150 of them shown

3-phase charging stations in Europe

In Europe 3-phase Level 2 charging stations are being installed on various locations. Lemnet.org is a good source for locating these charging stations, although not all are listed. As you might see, the charging stations in the Netherlands (and Amsterdam) and France (Paris) are missing. In reality the number is much higher! (Add the 250 from Amsterdam and 559 from E-Laad)

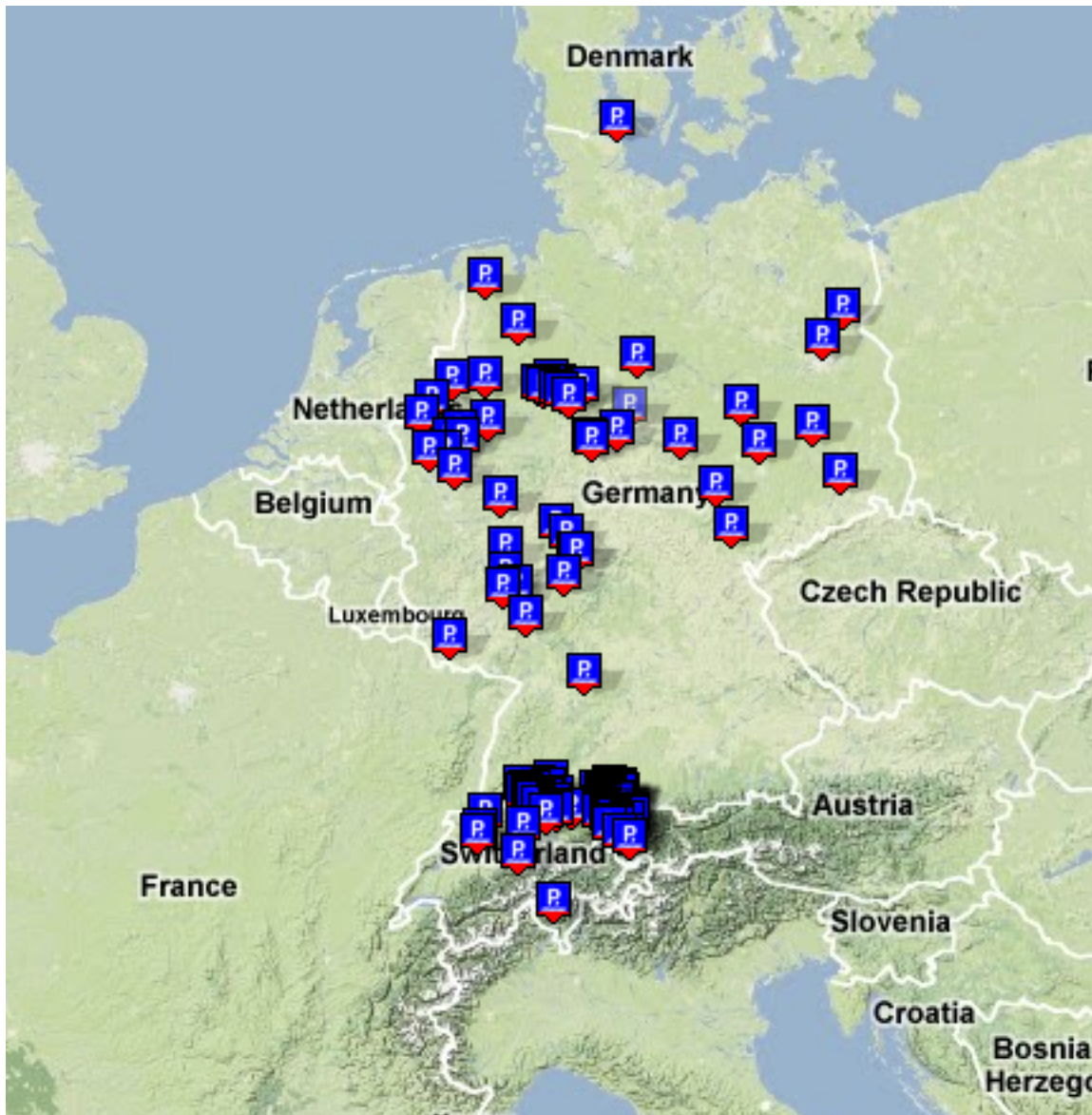
It does however show that 3-phase charging stations are common in Europe.

Total number (14-10-2011): **1,136** (See the note below the map!)

Available power: 2x11kW

Connector: 2x Type 2 (IEC 62196-2-2)

Source: <http://www.lemnet.org/>



Places within the map area: 1136 entries, 150 of them shown

3-phase connectors “in the wild” (1/3)

I've named it multiple times; 3-phase connectors can be found everywhere in Europe. Not only charging stations are 3-phase, but hotels, restaurants, farmers, (small) office buildings, homes also have 3-phase connections.



On the local market two 3x32A (Red) connectors. The market uses them for cooling and heating equipment.

At a farmer you'll probably find one or more of these 3x16A connectors.

Farmers use these for various tools.



3-phase connectors “in the wild” (2/3)



This picture was taken in Germany. On the pillar you see a 3x16A (left) and a 3x32A (right) connection.



Here you see the three phases coming into a house. In this case only L1 (brown) was connected, but L2 (black) and L3 (gray) are present.

3-phase connectors “in the wild” (3/3)



Various buildings have 3-phase connectors installed on the outside. In this case a 3x32A connector was mounted on the outside for general usage.