"Zero Carbon World": Opportunities and Threats for New and Old National Economies because of Energy and Industry Transition

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Key words: Zero Carbon, 100% Renewable industry, Greenhouse gas emissions, photovoltaics, battery storage

Abstract:

First a rationale is given why we need a "Zero Carbon world" and why this will cause an energy as well as an industry transition. Second it is identified what is necessary as a future economy for not only to stay competitive with existing technologies but even more to participate in tomorrow's big industries in an international environment. With two case studies, photovoltaics and batteries, Germany as example for an old economy and China for a new economy it is concluded that old economies cannot rest on their successful old industries and if they do, new economies can kick-start new industries with appropriate boundary conditions and take the global lead.

1. Introduction

According to the Paris agreement the world has to move as quickly as possible towards a Zero-Carbon world. This can be done expressly and least costly with renewables, notably photovoltaics and wind with appropriate energy storage. This necessary transition together with the needed infrastructure implies a new and huge production industry for those new products. In addition the Zero-Carbon world has also to end transportation fueled by oil. This will also cause a transition from the existing combustion engines for all transportation sectors towards electric motors (batteries and fuel cells) and green fuels for aviation. Another important sector for today's CO_2 – emissions is the heating (oil and gas), ventilation and air conditioning (electricity) of houses which can be overcome by proper insulation. The introduction of green hydrogen, produced by hydrolysis of water with renewable electricity, is also needed urgently to suppress greenhouse gas emissions. This energy transformation will cause a fundamental industry transition: not only will existing power plants become obsolete and be replaced by a fleet of renewable power systems, but also many traditional machines and processes will be replaces by new ones. Examples are the replacement of combustion engines by electric motors and the old steel making process using coal by usage of green hydrogen.

2. Why "Zero Carbon World" and energy transition towards 100% Renewables

The energy situation for 2015 is shown in Fig.1 (left). The primary energy of about 160 PWh (Peta = 10^^15) is still dominated by fossil fuels (~80.5%), seconded by biomass (mainly firewood, ~10%), nuclear (~5%), hydro (~2.5%) and other renewables (~2%). The secondary energy of about 100 PWh contains ~22% electricity and the rest is petrol, oil, gas and (process)heat [1-3].

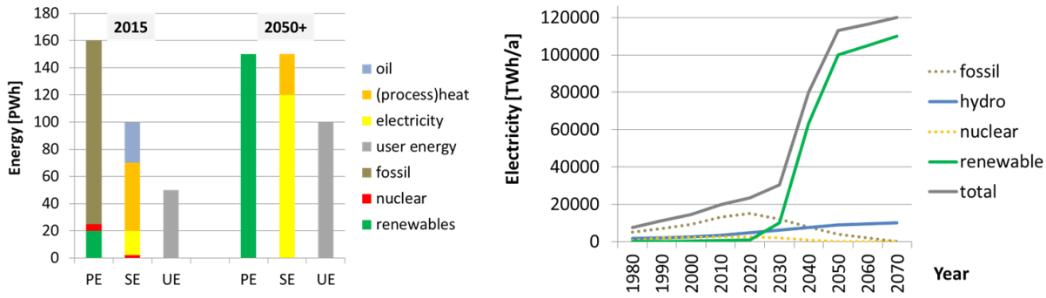

Fig. 1: *Left picture*: Prime, secondary and (end)user energy (PE, SE and UE) for 2015 [1-3] and 2050+ [4,5]; *right picture*: implication for development of electricity production

The losses associated with the transformation into what we really need, the end user energy are still ~50% due to a number of machines and devices, ready to be replaced by more efficient ones. One important aspect in today's energy scenario is the fact of inequality: only a quarter of mankind (~2 bn) consumes three quarters of energy (~75 PWh SE). Energy efficiency increase could realistically decrease this number by a factor of 2.5, resulting in 15 PWh SE usage for 1 bn people with today's quality of life as we know it from our privileged countries [4, 5]. Assuming this energy efficiency increase and a future population of 10 bn people [6] we can anticipate a future SE level of 150 PWh by allowing everyone the same quality of life as we have today. The dominance of fossil fuels today is the main cause for the increasing levels of green-house gases due to CO_2 -emissions.

In order to meet the important Paris goal to limit the greenhouse gas emissions at a level to keep the temperature increase well below 2°C, better 1.5°C, it is important to realize that not only the CO_2 – emissions from burning coal, gas and oil must be taken into account, but also the contribution of other greenhouse gases like methane, N_2O and F-gas as well as the increasing land use change (burning of jungle for pasture and agriculture). Normally the effect of these additional contributions is calculated in CO2 – equivalents. As seen in Fig. 2 (left), the global CO_2 – emissions from fossil sources amounted in 2017 to ~37 Gt, while another equivalent of almost 50%, namely ~16 Gt, was contributed by these additional processes. The above mentioned temperature increase of below 2°C will only allow a cumulative equivalent of ~800 Gt CO_2 , which is reached in only 13 years if we continue as in 2017 (Fig.3). Therefore we must drastically change and not only allow no further increase but to reverse the situation and emit quickly less towards the "Zero Carbon economy". Looking to the most important contributors as seen in Fig. 2 (right) it is obvious that this will be a major challenge: only Europe and less US decreased the emissions over time, Russia, Japan and also China, after a sharp increase due to its industrialization, stayed ~constant. The big question is with India, Latin America and Africa. If there industrialization were to follow the same pathway as China, the additional 800 Gt would be reached very quickly in less than 10 years.

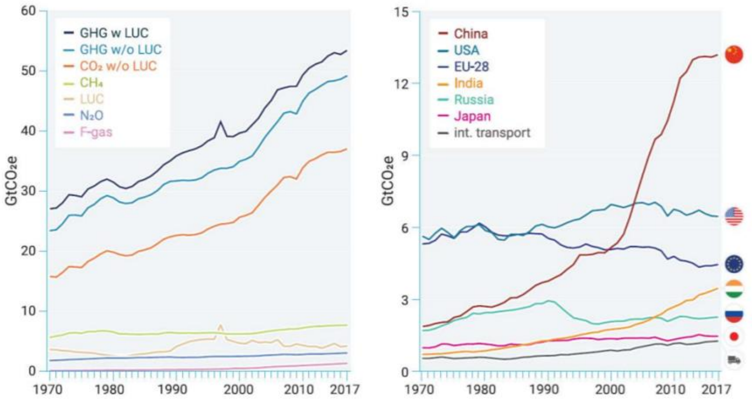

Fig. 2: *left*: Global Greenhouse Gas Emissions ([7], including LUC = land use change), *right*: development of Greenhouse Gas Emissions in major industrial countries

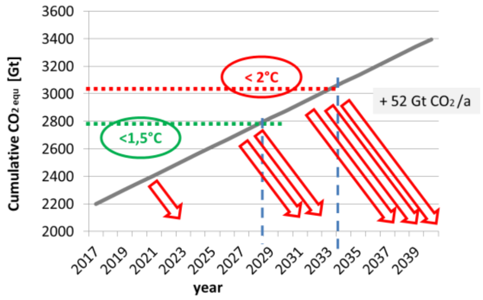

Fig. 3: Cumulative equivalent of atmospheric CO2 and two scenarios for keeping the global temperature increase below 1.5 and 2°C, respectively, at a constant annual increase of 52 Gt CO2 (2017 level)

Very fortunately the world has seen in the last 10 years an abrupt drop in prices for renewable technologies, in particular PV and wind (Table 1). There is now widespread acceptance in the fact that already today PV and wind are the lowest cost electricity generating technologies with LCOE (Levelized Cost of Electricity) in the range of 2-5 $ct/kWh, compared to >20 for new nuclear and >10 for clean fossil [4]. Even adding storage cost (<5 $ct/kWh) makes renewables plus storage cheaper than traditional technologies [8].

Electricity generating technology	Price [$ct/kWh]
PPA (Power Purchase Agreements) new nuclear (Hinkley Point, UK)	20(+)
„clean coal/gas“ (CSS)	>10(+)
PPA new wind parks (on- and off-shore)	~5(-)
PPA new PV power stations (>10 MW) northern regions (Ger, UK) southern regions (Arabia)	~5(-) ~3(-)
Electricity storage with large scale batteries	~5(-)

Table 1: Today's prices in $ct/kWh for various electricity generating technologies including storage cost; (+) indicates future increase and (-) future decrease of prices

The annual energy offered by renewable energies in a sustainable way has been estimated by [9], which concludes that 90% is attributed to solar, 9% to wind and only

1% to all other renewables (including hydro, biomass, geothermal, wave and tidal) and is shown in Fig. 4. The total amount was calculated to >3,000 PWh, which exceeds the future needs described above by a factor of 20. In order to allow for the local offerings from e.g. geothermal, hydro, biomass/waste, wave/tidal and also wind a simplified contribution from the various renewables was suggested [4, 5] to be 60% solar (with PV adding most), 20% wind and 20% all other renewables.

The consequences by changing (1) all primary energies to renewables, (2) to assume an energy efficiency factor of 2.5 and (3) to use mainly electricity producing renewables like wind and solar are significant compared to today's situation as seen in Fig.1: (i) by definition the primary energy is equal to the secondary energy, (ii) the relative contribution of electricity to the SE increases from ~20% to 80% and (iii) the end user energy increases significantly, which allow all of the future 10 bn people to have a similar quality of life as we, in today's industrialized world, have now.

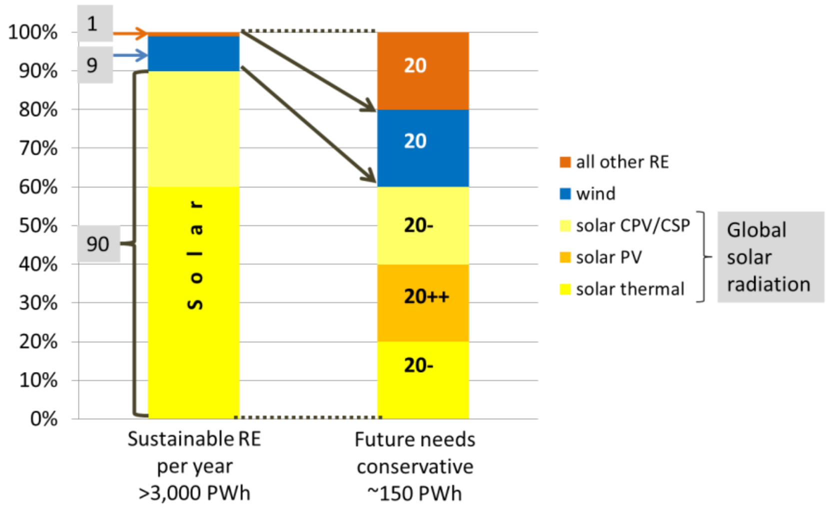

Fig. 4: Globally available sustainable renewable energy (ref.: WBGU Germany [8]) and the future needs together with the contribution from the various energy generating technologies (ref.: W. Hoffmann [4, 5])

3. Industry transition as consequence of a Zero-Carbon world

3.1 Electricity generation

One important consequence of the projections described above is a complete change of the globally existing fleet of electricity generating power plants: all fossil and nuclear plants will be replaced by predominantly wind and solar power plants as seen in Fig. 5. A study by [10] has shown that such a global change can be done not only environmentally safe but also cost effective.

Fig. 5: Exit from traditional non-renewable sources (fossil and nuclear power stations) towards mainly to wind and solar

3.2 Mobility

Another important contributor to the global CO2 – emissions is mobility, which accounts ~one quarter of today's secondary energy use, mostly fossil fuels (petrol and diesel for cars, trucks and buses, kerosene for planes and heavy crude oil for ships). A zero-carbon world needs a complete change away from these fossil fuels. This can be done in two different pathways:
(1) replace fossil oil by liquid biomass. This would allow to use the existing infrastructure to store and distribute the green fuel and also to continue the use of combustion engines. The first would please the international oil and gas companies and the second the international car manufacturers. However, this has a tremendous drawback: the areas needed to grow all this necessary biomass would compete with the urgently necessary areas for food production. It also has been demonstrated that the same area of land can deliver 50 to 100 times more energy in form of electricity from PV and/or wind compared with the energy content of biomass [4]. Therefore we suggest a second pathway:
(2) replace fossil oil by green electricity. This would allow to use electricity directly with batteries in all those applications, where recharging must not happen too often within a day, typically cars, which drive in 80% of normal use less than 100km per day. For those travelling >1,000km per day, buses and trucks one could use fuel cells driven by hydrogen derived from hydrolysis of water with green electricity. Ships could best use LNG (liquid natural gas), but produced from green hydrogen plus CO_2 to obtain methane ($CH_4 \simeq$ LNG). For the foreseeable future the long range planes would best be fuelled by green fuels made from methane and processed further to bio-kerosene. This is shown in Fig. 6.

Fig. 6: The future of mobility – cars, lorries, ships and planes

A simple reason why this differentiated pathway (2) described above will realistically continue to use three different technologies is shown in Fig.7: for all 3 cases we start with 100 kWh green electricity and calculate the distance travelled. The e-car with a battery can travel ~600km by using the stated efficiencies. In the case of fuel cells we have to take the two efficiency drops electrolysis (~75%) and fuel cell (~75%) into account, resulting in 56% (in comparison with 90% for the battery). Hence this fuel-cell driven car can only travel 333km. In the third case of green fuel we have to take into account the efficiency of methanisation (~50%) and the

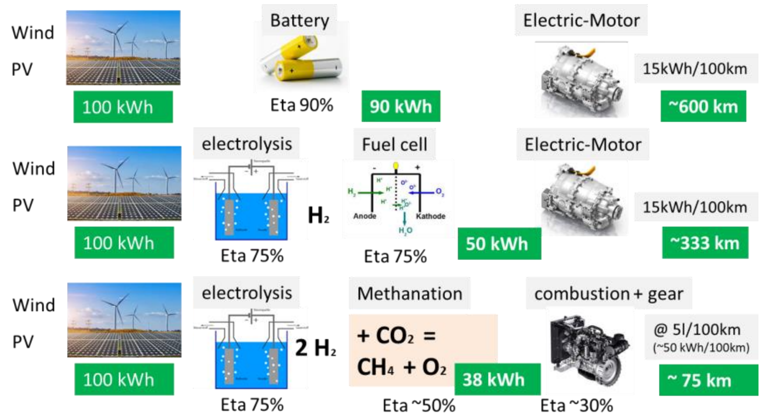

Fig. 7: Mobility: distance covered for the same amount of RE for different technologies

lower efficiency (~1/3) for the combustion (+gear) engine compared with the electric motor. This will only allow for a distance of 75km.

The fuel cost (only) for the 3 discussed cases is shown in Table 2 together with today's fossil fuel cost in a typical combustion engine. The following simplifying assumptions have been made: (a) for today's petrol price we have excluded the tax, (b) for the PV electricity cost we have used the Northern Europe amount which would bisect in sunny regions in the south and we have added a margin for distribution and selling the PV electricity of 50%, (c) the cost for chemical transformation from hydrogen to methane/green fuel was not taken into account and would increase the stated number. The comparison shows that the very distinct cost ranges for the 3 cases will allow these different application routes in the future. If we include the simplified technology and lower cost for the electric motor compared to the combustion engine will further trigger the change away from today's combustion engine. Only for the application where the high energy density fuel kerosene is a must – as for planes – the high price for this green fuel is justified and will be paid.

technology	calculation	Cost [$/100km]
Combustion engine	5 l x 80 $ct/l (w/o tax)	~4
E-car (battery)	15kWh x 5 $ct/kWh x 1,5*	~1,1
Fuel cell car (hydrogen)	27kWh x 5 $ct/kWh x 1,5*	~2,0
Combustion with green fuel	50kWh x 5 $ct/kWh x 1,5*	~>3.8**
Beside no CO2 –emissions e-and fc-cars (with RE – electricity) are significantly less expensive compared to old combustion engine → quick transition!		

* Includes distribution & selling of RE-electricity

** excludes the cost of chemical transformation

Table 2: Fuel cost per 100km for various technologies

3.3 Houses

The heat requirement for houses changed significantly from the past with typical ~75 W/m² towards ~50 W/m² and is further reduced with low energy and passive houses down to 15-30 W/m² (Fig. 8). With these lower requirements we can reduce the amount of oil and gas accordingly and the remaining needs for heating and cooling can be done by solar thermal and PV.

Fig. 8: Development of heat requirement for houses from the past into the future

3.4 Chemistry

As a last example how the industrial landscape will change due to the required Zero-Carbon world we take a look into the global chemical industry. In Fig. 9 is summarized how green hydrogen can be used in a variety of important chemical reactions.

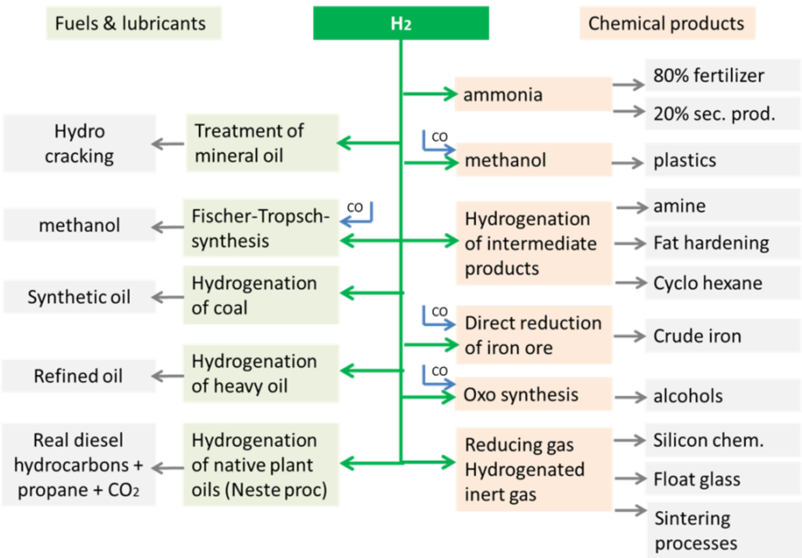

Fig. 9: The importance of green hydrogen for the chemical industry

As a specific example we take a look into the global production of steel as shown in Fig. 10. Today iron ore is reduced by coal which amounts to 2.7 Gt CO_2 representing an astonishing 7% of the global CO_2 –emissions. These emissions can be omitted when green hydrogen is used as shown in the lower part of the Fig. 10.

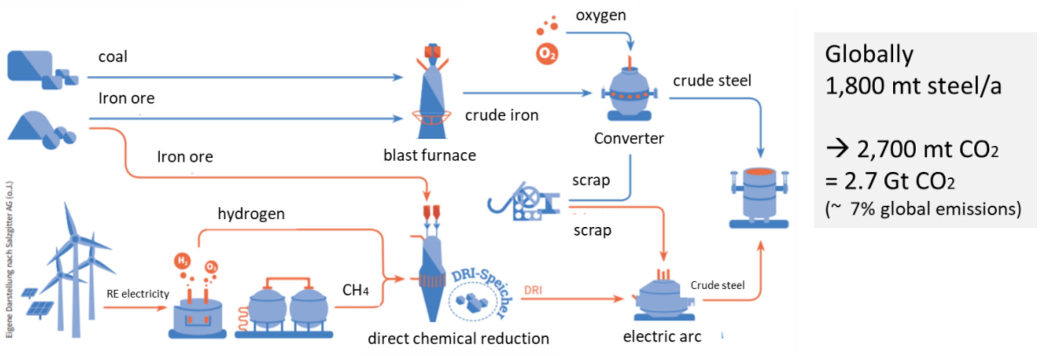

Fig. 10: Impact of green hydrogen to reduce significantly the CO_2 emissions for steel production (lower part: iron ore plus hydrogen) in comparison to the traditional process (upper part: iron ore plus coal)

4. "Old" and "New" national economies

It is interesting to analyze how different national economies have tackled the findings described before. We will take a closer look what happened in Germany – representing also some other countries in Europe – as an example of an "old" economy and China representing a "new" economy. Before this we will shortly analyse the two countries in the years of 2000 to 2010.

The industrial economy in Germany in these years can be characterized by:

- Well-functioning electricity production and infrastructure since many decades run by well-established oligopolistic national utilities (e.g. RWE, eon, Vattenfall)
- Many SME's as "hidden champions" serving global and national big industrial conglomerates in the machine building sector
- First of its class automobile production industry with best combustion engines (e.g. Mercedes, BMW, Audi)
- Big chemical industries (e.g. BASF, Bayer, Merck)

The situation in China was quite different:

- Big efforts to industrialize the country by investing many GW coal fired power stations (compare the increase of CO_2 shown in Fig. 2)
- Manufacturing for many international companies (toys, but also semiconductors)
- Cheap work force
- Clear goal to not only have production as a service, but establish an own production industry in areas where globally needed products evolve
- A population of more than a billion people where most had a low living standard. Private companies at that time did not exist
- Last, but not least a strictly organized country with a one-party state

5. Case study "Photovoltaics"

The annual installations for PV systems [11] are shown in Fig. 11. They can be clearly divided into three phases: a **1st phase** until 2011, where Europe had installed up to 80% of the globally produced PV components. The **2nd phase** reaching out to

2017 with China as the single country installing > 50% of globally produced products. Since then we have in the **3rd phase** a situation, which is better suited for the global production industry, as we have a more balanced situation for the PV installations in the various countries globally. We will now take a closer look into why this happened as described.

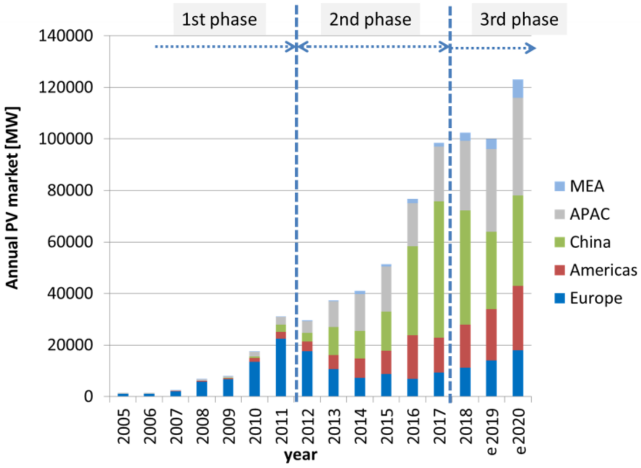

Fig. 11: Three distinct phases in the development of the PV development [11]

1st phase: The "green movement" and the establishment of the political party "Die Grünen" in Germany in the 1990/2000 years made it possible to ask for a cleaner environment. In order to push the installation of green technologies – PV and wind – a special Feed-in tariff (FiT) system (EEG, renewable sources act) was introduced by Hans-Josef Fell which was supported by Hermann Scheer from the then ruling party SPD (social democratic party). It should be remembered that in 2000 the LCOE of PV electricity in Germany was ~50 $ct/kWh, much more compared to the price of ~20 $ct/kWh from the grid to domestic houses in these years. Only with a FiT based on the LCOE plus reasonable margin private people would invest in a PV system. This was done and private investors could count by law on an attractive return on investment for 20 years. This caused a strong growth of installed PV systems in Germany, starting in ~2000. Few years later a similar FiT was introduced in other EU-countries, which accounted for the shown increase up to ~22 GW in 2011.

In parallel to this market development a number of European companies invested in the manufacturing of PV solar cells and modules (e.g. RWE Solar, Siemens Solar, Bosch Solar, Q-Cells, Solarworld, BP Solar, Shell Solar), feedstock silicon (Wacker), materials like silver paste (Heraeus), glass and encapsulation foils, inverters (e.g. SMA, Fronius, …), production equipment (e.g. Schmid, Manz, Baccini, Centrotherm, …) and BOS-components (e.g. Schletter, …). There was also an increasing number of companies to plan and install the PV systems (EPC's (engineering, procurement and construction) and whole-salers, e.g. Phoenix Solar, IBC, Densys/PV5, Solnet group, MHH Solartechnik, …). While most of the non-PV cell and module companies named above are still active in this field, all of the PV cell and module producers from above exited the business with only small niche module producers in place today. Beside feedstock silicon, the specific investment was highest for Si-crystals, wafer-, cell- and module production, which was one of the reasons why until the late 1990s only companies within bigger conglomerates survived in this field (like RWE, Siemens, BP, Shell). This changed when after the market increase for PV in Germany/EU entrepreneurs (like the founders of Solarworld and Q-cells) could successfully place an IPO and could use the money for investments. Unfortunately, the subsidiaries of the big conglomerates were either ended or sold to other companies as the needed investments did not fit into the portfolio of the respective mother company.

The situation in China was quite different. When in the late 1990s the content for the 9^{th} 5-year plan (1995-2000) was discussed, politicians together with industrially experienced managers and scientific institutions analyzed the landscape for future products. Photovoltaics was found to be one of the sweet spots. The market increase in Europe, paid by the millions of electricity consumers, was taken as a good market entry for solar cells and modules produced in China and exported to Europe. The Chinese government put aside a big investment sum (a report from the "Deutsche Bank Research" concluded a sum of ~50 bn $) which was foreseen via the Chinese state bank for investments in PV manufacturing plants. At the same time the government also allowed to start privately owned companies. Hence some entrepreneurs started their PV manufacturing, asked low interest money from the Chinese State bank and also went to the New York Stock Exchange to get additional money. The author remembers Mr. Shi Zhengrong from the company Suntech who very successfully built up the then biggest solar cell and module producer and became the first billionaire in the PV community and one of the first in China. Manufacturing of solar cells and modules kick-started in ~2004 as seen in Fig.12 and reached from almost zero within 7 years a global market share of ~60%. The further development is difficult as indicated, as Chinese companies have in the last years started subsidiaries in other countries. Two important facts contributed to the quick increase of market share:

(1) The companies for production equipment in Europe profited from the joint development together with European cell- and module producers (named above) and the excellent research community (e.g. Fraunhofer-ISE, ISFH) to not only build hardware to process wafers into efficient solar cells but also to know the process parameters for the individual process steps. Chinese manufacturers were able to purchase the latest state of the art technology for their production and translated it towards economy of scale.

(2) Most of the EPC-companies in Germany/EU took advantage of lower priced modules from China to maximize their profit. Major reason for the lower prices was the fact that the quick ramp-up caused a severe overproduction globally with subsequent prices below production cost and with the bigger economy of scale and new equipment Chinese manufacturers could produce at less cost compared to much smaller German/EU based companies.

2nd phase: The flip-side of the nice increase of PV installations in Germany/Europe was the recognition by the utilities that a measurable amount of electricity was produced by former customers and taking business away from them. This ended in political decisions which drastically reduced the FiT, thereby reducing the potential return on investment and resulting in a quick decrease of annual PV installations in Germany and also in other EU-countries as seen in Fig. 11.

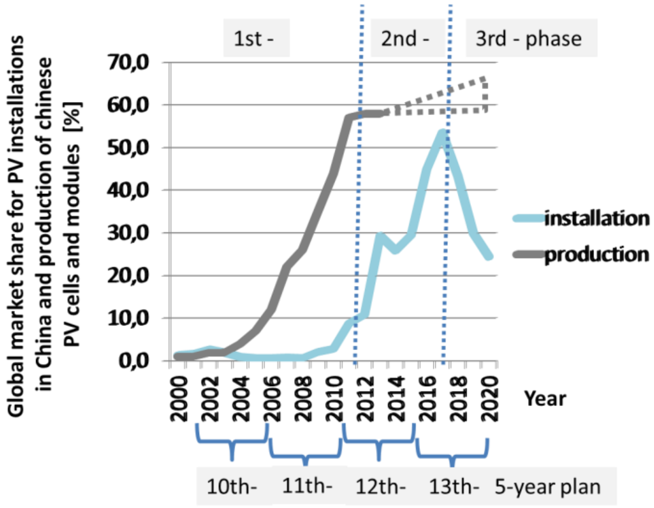

Fig. 12: Market share for production and installation of PV solar modules in China [11, 12]

When China realized that all of a sudden their major markets in Europe collapsed with no other market in place they had only one choice: create a local market to absorb all the PV components from the existing Chinese production industry. In addition in Europe and US anti-dumping duties and anti-subsidy countervailing duties on Chinese PV products were enforced which made exports to EU and US difficult (minimum import prices for solar cells and modules in EU). As seen in Fig.11 China showed a similar astonishing development for the local market: starting in 2010 it took again only 7 years to grow the market from just a few MW towards ~52,000 MW in 2017, which represented a global market share of >50% (see Fig.12).

3rd phase: as seen in Fig.12 there is a dramatic decrease in the market share of Chinese PV installations caused by a significant decrease of installed GW. From Fig.11 this decrease is from ~52 GW in 2017 down to 44 and 30 GW in 2018 and 2019, respectively. The official statements from the Chinese government can be summarized as follows: **(i)** the cumulative installations in 2017 with ~130 GW exceeded already by 20% the goal from the 13th 5-year plan for the year 2020, which was set at 105 GW; **(ii)** the preparation for the 14th 5-year plan is concentrating on shifting the ~100% subsidy-driven PV installations, in particular the large green fields, towards ~100% subsidy-free PV market, notably to increase the share of domestic and decentralized PV systems [13].

It is tempting to speculate on an additional reasoning **(iii):** with the 50% market share of global installations it is possible to influence significantly the pricing of solar modules, when a major change of the global market is initiated. Hence, with the decision to decrease the Chinese market by 23 GW within 2 years the global market of ~100 GW was affected negatively by >20%. Knowing that we have globally still overcapacity in the production of solar cells and modules the consequence is a fierce market competition with unhealthy prices. This could help to maintain the global market share of Chinese producers.

There is another development in China worth mentioning: after the successful achievement of >60% global market share for producing wafers, cells and modules with imported production equipment and important materials the goal formulated in the 13th 5-year plan (2016-20) was the achievement to have new production equipment and materials to >80% made in China. Again, as often in China, this goal most probably will be exceeded in 2020.

As seen in Fig.11 the PV market started to increase again in Europe as also in many other regions in the world. This may mitigate a little the (iii)-reasoning from above and allow the global manufacturing industry to export into a more balanced portfolio of countries with a sizable PV market. Also it may trigger at last moment the buildup of manufacturing along the value chain in Germany/EU, India and other countries. Indeed, in 2021 new production companies for solar cells and modules were started in Germany: Oxford Industries (production of Silicon/perovskite tandem cells and modules) and Mayer Burger (production of HJT- solar cells and modules).

6. Case study “Li-ion batteries”

The most influencing industry in the development of Lithium-ion batteries is the automotive industry. The pioneer Tesla who cooperated with Panasonic, one of the leaders for Li-ion batteries, paved the way towards e-mobility. It was China again which pushed this new mobility concept into economy of scale. It was clear that Chinese car manufacturers would have a hard time to compete with German/EU car manufacturers on the basis of combustion engines. Hence there was a window of opportunity to enter into the car manufacturing arena with a new concept. New manufacturers, like BYD (build your dream), quickly ramped up production of electric cars and also batteries. The company Geely has the clear goal to produce by 2020 90% e-cars from their production portfolio. Remarkable is the strategic purchase of international companies like Volvo and London Taxi as well as the investment as largest single stockholder of Daimler AG by Geely. Among the three biggest producers in 2019 for Li-ion batteries are two Chinese: After LG Chem (51 GWh capacity) from Korea are CATL (Contemporary Amperex Technology Ltd. with 40 GWh) and BYD (25 GWh) from China. The pace of Chinese companies to conquer top market positions in future industry areas on a global scale is admirable.

In contrast we had in Germany a completely different attitude in this field: being the most advanced car manufacturing country with highly sophisticated and best-of-its-class combustion engines and smooth automatic gearboxes the old CEO’s like Mr. Winterkorn from VW and Mr. Zetsche from Mercedes neglected the change towards electric cars. Very arrogantly they argued publicly that for many more years to come e-cars will not be able to compete. When the EU started to install clear goals and limits for the average number of CO_2 emissions for each fleet of the respective car manufacturers it became quickly clear that even the best combustion engine will not be able to reach this. However, unfortunately, the management tried to meet these goals by introducing defeat devices which let into what is known as the Dieselgate scandal starting in September 2015. By today the new management of the before mentioned companies have completely changed. Late, but hopefully not too late they will be able to make this turn-around. Recognizing Germany and EU as relevant e-car market there are also two foreign investments worth to mention: Li-ion battery production by the Chinese company CATL in Thuringia/Germany and Tesla (car and battery) in Brandenburg/Germany. In addition, German carmakers are planning with consortia to build also battery factories in the near term. In this context it is worth mentioning that these consortia in Germany are offered substantial support from the ministry of economics both in terms of money and arguments in media. This willingness was not seen 15 years before when the PV industry asked for similar support. One could speculate why this is the case: batteries are an essential part of future e-cars and the automotive industry is seen in politics as a very important part of the economic welfare in Germany; 15 years ago in the case of PV there was no supporting industry behind this – in those days expensive – new way of electricity production, even more, utilities were successfully fighting against this decentralized technology.

7. Conclusion

What are the lessons learned from these exercises? We will discuss five supporting measures which are seen as decisive for the establishment of new products and services in a country: **First**, it is obviously sometimes obstructive to have a long running successful industry for important services in a country which hinders the introduction of new products and services. **Second**, an open minded analysis including politics, industry and science can help a lot to identify future important products and services. **Third**, once a product is chosen which only by economy of scale will be able to compete against the old existing products, an appropriate market support must be defined, which enables the end customer to decide for the new product. **Fourth**, if the production industry for this new product is seen important for the economy well aligned financial measures have to be in place and, last but not least, **Fifth**, companies and highly motivated managers must be available with an attitude of reaching shortest “time to market” to produce at economy of scale quality products and sell these in a competitive market environment.

For this we have analyzed in two countries – Germany as an old economy and China as a new economy - the two areas: technology for producing electricity (PV) and the mobility sector (batteries). Tables 3 and 4 summarize our analysis:

PV	**Germany** (old economy)		**China** (new economy)	
(1st)	Since many decades established utilities with strong ties to politics → no interest to change	**-**	Electrification started in the 1990s due to the industrialization program with steep increase – open minded	**+**
(2nd)	Fragmented groups with very different interests	**-**	One state party defines 5-year programs with all groups	**+**
(3rd)	The green party together with social democrats established Feed-in tariff	**+**	A Feed-in tariff was defined to grow the market	**+**
(4th)	Because of strong old industries there was no need to push for new ones	**-**	Strong interest to conquer new and future industries, embedded in “Made in China 2025” program	**+**
(5th)	Available, but short “time to market” is often hindered	**0**	Available with also short “time to market” philosophy	**+**

Table 3: The five supporting measures as seen in Germany and China for PV; ; + and – indicate a positive and negative attitude to each of the 5 supporting measures, respectively, 0 means neither/nor.

As seen in Fig. 13 the electrification in China started parallel to the industrialization program. Today China has the highest electricity consumption globally and this with a gigantic fleet of coal fired plants. The pollution in most cities is harmful to the population which is a major reason to install increasingly renewable technologies like wind and solar PV.

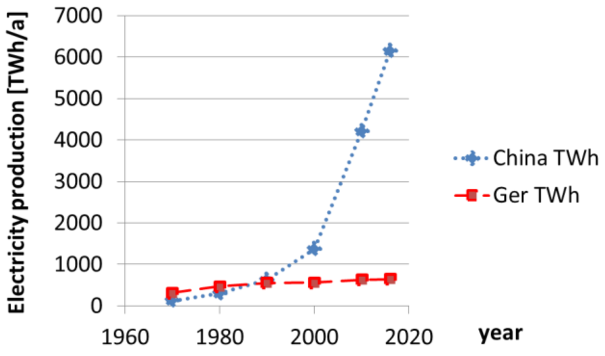

Fig. 13: Electricity production in Germany and China

The mentioned "Made in China 2025" program sets the clear goal that national champion companies should be developed in 10 high-tech industries, including robotics, semiconductors, electric vehicles and renewable industries like wind and PV.

Looking to the qualitative assessment for the 5 supporting measures it is obvious that Germany with only one "+" and one "0", but three "-" is far behind China which shows five "+" for this new industry. As a result it is not surprising that in Germany, but also in the other European countries there is no longer a production company for PV wafers, cells and modules compared to the >60% market share globally in China.

Table 4 summarizes the situation for batteries for e-cars:

Li-ion battery	**Germany** (old economy)		**China** (new economy)	
(1st)	Since many decades many big and powerful car makers with best of its class combustion engines → no interest for e-cars and batteries	**-**	Although biggest market there is strong dependence to cooperate with foreign car makers in Joint Ventures → strong interest to have own technology	**+**
(2nd)	Strong interest to keep the old technology	**-**	Very open minded to develop new technologies like e-cars	**+**
(3rd)	A buyers premium is demanded and approved from politics	**+**	High subsidies have been given to kickstart the sale of e-cars	**+**
(4th)	Because of strong old industries there was no need to push for new ones	**-**	Strong interest to conquer new and future industries, embedded in "Made in China 2025" program	**+**
(5th)	Available, but short "time to market" is often hindered	**0**	Available with also short "time to market" philosophy	**+**

Table 4: The five supporting measures as seen in Germany and China for Li-ion batteries;
+ and – indicate a positive and negative attitude to each of the 5 supporting measures, respectively, 0 means neither/nor.

Again the analysis shows that in Germany with one "+", one "0" and 3 "-" compared to the 5 "+" evaluation in China, it is not surprising that today only one Chinese company (CATL) is producing in Germany for the European e-car market, but no single German company. Fortunately, the before mentioned consortia with VW are ramping up production and are aiming to reach competitiveness not only by economy of scale, but also with new technologies (solid state Li ion batteries).

One important result from this analysis is obvious: when old economies rest on their well-established old technologies with even reluctance to start new ones, new economies have an easy time to conquer the production leadership for the future, new and better products. Of course, Germany and the other European countries cannot push decisions as the state party in China – but we must find appropriate measures and financing instruments if Europe as an old economy would like to keep its quality of life and welfare.

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9. Acknowledgement

I would like to thank many of my former colleagues from industry, scientific institutes and associations for many enlightening discussions and great friendship.