Transmission of dispatchable solar energy from North Africa to Central Europe – Denis Hess
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Ladies and Gentleman,

my name is Denis Hess. I'm working for the German Aerospace Center in Stuttgart about dispatchable renewable energies. At the DLR we are making worldwide research to enable a durable and efficient energy system.

Today I present you a scientific model of a potential civil project on eye level. Two variants of High-Voltage-Direct-Current transmission lines transport dispatchable solar energy from the Sahara desert in Morocco to one balancing authority area in southern Germany. We are speaking about 1500 MW net and 9.3 TWh/y. If you have got any questions during the presentation just let me know.

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For the model study the energy system of the member state Bade-Württemberg was analyzed and projected to an energy system with nearly 100% of renewable energies in the electricity sector.

Baden-Württemberg is one balancing authority area of Germany. We consider that a mix of primary decentralizes REs like PV and onshore Wind and with dispatchable REs e.g. offshore Wind, Water, CSP, Biomass and geothermal energy is an efficient option for a sustainable energy mix. The topology of the electricity infrastructure of HVDC must be a point-to-point connection to enable dispatchable energy for one balancing authority area. With this connection the dispatchable power plant is fictive installed in the balancing authority area but only connected with the HVDC link.

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For an energy system with nearly 100% RE there will be a paradigm change in the electricity sector. You see one summer and winter week each time for 2012 and 2050 in Baden-Württemberg. Today power plants cover the load with their characteristic efficient production. In the base load there are nuclear and lignite power plants, in the middle load coal power plants and in the peak load gas turbine and pump storage plants. In the future there will be only two load ranges: one with feeding of fluctuating REs and one with dispatchable REs.

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For a comparison we considered two scenarios with the aim of nearly 100% RE in 2050 for BW. Scenario 1 is the scenario with strong national RE expansion and scenario 2 with the import of dispatchable solar energy from North Africa. The difference between them is a higher environmental impact in scenario 1 because we need much more power plants, grids and storages. Therefore the average utilization of the power plant park with about 1000 h/y in scenario 1 is only the half of scenario 2. For our assumption the peak load must be covered at any time with firm capacity which will be until 2050 gas turbine power plants and the dispatchable REs. The decision for scenario 2 is already today necessary to enable a high average utilization and therefore an economic use for a relative expensive infrastructure of dispatchable solar energy.

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For a better understanding hourly time series of the power plants show the difference between the scenarios each time for one summer and winter week. After the year 2022 with the shutdown of all nuclear power plants in Germany and nearly 40% RE the ways of the further RE expansion split. While then an import of dispatchable solar energy is hardly possible when the average utilization is too low. We speak from the so called integration window of dispatchable solar energy, which is best opened when there are huge fossil power plants with a high average utilization to substitute.

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As a result of the scenarios we see in the year 2050 an electricity system each time with nearly 100% RE in BW but huge differences of the electricity production. In scenario 1 we have domestic REs but also high production surpluses which will be destroyed in hydrogen gas storages in case a sufficient grid infrastructure is able to transport the surpluses. Another problem will be the dependency of gas which will be imported from Russia in one or two pipelines and therefore can be possible utilized as a political energy weapon when gas is indispensable to supply BW with electricity. On the other side scenario 2 has a balanced energy portfolio with the import of dispatchable solar energy, less surpluses and therefore an ideal power mix. To align a durable energy mix for the aim of 100% RE we have to decide for one of the scenarios already today!

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How is the technology of dispatchable solar energy working? The concentrating solar power plant works with direct sunlight. The parabolic mirrors collect the sunlight and heat the heat pipe up to 400°C. The heat flows either direct to the steam generator and to the turbine or to the thermal storage. With the thermal storage electricity can be produced day and night even for days when sun is not shining – solar energy can therefore be considered as dispatchable. In case the storage is empty a co-firing with fuels of all kind can ensure firm capacity. After the generator the electricity is converted from AC to DC to enable a low-loss transmission with overhead lines or cables until the converter in the balancing authority area in Central Europe. Here electricity is converted from DC to AC and fed in to the grid. For a net import of 1500 MW a gross capacity of 2200 MW CSP must be installed in Morocco. The losses of about 30% can be reduced while 22% accrue in the power plant itself. For 2200 MW a surface of about 150 km² for this configuration would be needed.

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An exclusion mask prohibits a surface conflict. Especially for Morocco the slope above 2% is dominant. For the scientific analyses we chose two exemplary model sites. One is near Marrakech and the other near Missour each with more than 2300 kWh/m²y. The economic CSP gross land demand in the northern part of Morocco is at about 18500 km² CSP. One site with 150 km² needs only 0.8% of this potential.

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The overview of the two variants shows the costs and the required land area. The two routes are calculated with a computer based algorithm which follows exclusion areas and cost criteria. The red route goes from Marakesh to Daxlanden and the blue route, which does not cross the Pyrenees, goes from Missour to Eichstetten. The cost of the CSP power plant varies because CSP has with its beginning learning curve still a huge cost reduction potential. Therefore the cost of the CSP-HVDC plant are between 16 and 24 billion € with money value of 2010. The O&M costs are at about 4-5 €Cent/kWh including transfer costs. The Levelized Cost Of Electricity (LCOE) are about 12-15 €Cent/kWh. The project could be feasible until the end of 2024.

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The transfer costs in the model are calculated considering the environmental impact with the required land. For each required m² there will be a durable compensation payment. Therefore the new unit €Cent/(TWh·m²·y) characterize this compensation payment. Overhead transmission lines have got less investment costs then underground cables but in the model overhead lines cost more operation cost due to more required land. Considering the overall costs during 40 years, overhead lines and underground cables are cost neutral! Therefore a free choice of technology and better acceptance from the local population can be achieved.

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The transfer costs in the model are calculated with the standard land value in the affected nations. The costs per m² and year are at about 40 €Cent. The municipalities and land owner profit therefrom equal. A comparison shows that in agriculture in BW only 8 €Cent/m²y are generated. A **five time higher value** may achieve an intention from the affected people to want the electricity infrastructure. Today only the blue value is paid once in Germany for a new transmission line. Therefore we change the attitude from “not in my backyard – NIMBY” into “please in my backyard - PIMPY” with a durable and adequate payment. The costs for the consumers depending on the route configuration are at about 1 €Cent/kWh.

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In the model people do not only profit from a permanent payment but can decide if and how the infrastructure might be implemented. Starting from the project idea and the political intention, citizens will be informed active from media for example social networks and NGOs. Citizens can make petitions and public decisions on a multinational online communication platform and thus influence the representative democracy. But the elected representatives in parliament decide ultimately, whether such a project is intended or not. This decision is in the red traffic light phase, however, can only be understood as a framework decision rather than a dictation already concretized in details of the project. This has the advantage that it can be decided for the public good and not make minorities influencing the decision. With a positive decision for the project you now enter the phase of the yellow light.
In the planning phase of the project, affected citizens can play part in participatory democracy through deliberation (consultative decision) with the proposal of alternative solutions, especially in order to avoid conflicts. The limits of the decision are not primarily the

construction costs, but are rather in the technical and legal possibilities and must be discussed with feedbacks in the population. For the communication, modern 3D interactive visualization technologies can be used with cadastral and cost data. Artistic pylon structures based on local sightseeings also create the possibility of a connection character among multiple municipalities.
If an agreement of the project is achieved you're in the green phase of the traffic light model - the implementation. Here there is legal certainty for the project executing organization and investors.
During the project implementation an ongoing evaluation provides information to the affected citizens as a control option to obtain an evaluation of the entire project. Finally future projects can benefit therefrom.

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A time frame is needed for the planning and integration of the CSP plant in the power plant park of Baden-Württemberg to assess the need and the design of the power plant in time. The schedule describes on the basis of the traffic light model, the necessary duration of the process. Here, the total time of decision-making, planning and building (traffic signals) is reached with 10-15 years. Politics and the population should make the framework decision in 2014 therefore under optimistic assumptions the CSP-HVDC plant could provide electricity to Germany in 2024. A shift of the decision of intent inevitably leads to time displacement of the entire process.

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Considering the costs of 16-23 billion € the question is how can this investment be paid that low interests incur and thus the capital costs remain low? The answer is a short capital repayment period and guarantees like AAA and PPA (Power Purchase Agreement). With a short capital repayment period the tariff will be high but only for a short time. To enable a payable tariff, the tariff should be apportioned on a high number of consumers, because all consumers profit in an European electricity market.

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The chart shows the tariff of the CSP-HVDC site as a function of the capital repayment period. For a capital repayment period of one year the tariff will be at about 2.00 €/kWh for only one year and for the second year only O&M cost of about 0.04 €/kWh accrue.

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In the electricity mix in Germany the tariff of 2.00 €/kWh can be apportioned for all customers with 3 €Cent/kWh but only for one year. This is the so called apportionment for the CSP-HVDC plant. In a cooperation project with France and Germany for the occasion of the 50th anniversary of the Élysee contract the one year apportionment for both countries will be at about 1.6 €Cent/kWh. If an apportionment is made for all European it would be only 0.5 €Cent/kWh for one year. The benefits for all customers are in a European market constant electricity prices due to dispatchable RE. It would be even fair if the technology which has still a huge cost reduction potential with its beginning learning curve could be financed from all European customers to enable cheaper future CSP-HVDC projects for all customers.

The saving in comparison to fossil dispatchable energy is with a one year apportionment at about 3.8 billion € during the 40 years lifetime with the shown economic assumptions. If the capital repayment period is longer than one year, savings decrease.

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Conclusions

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Communication platform…
Public participation with declaration of intent on different levels

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Further steps

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Thank you for your attention!