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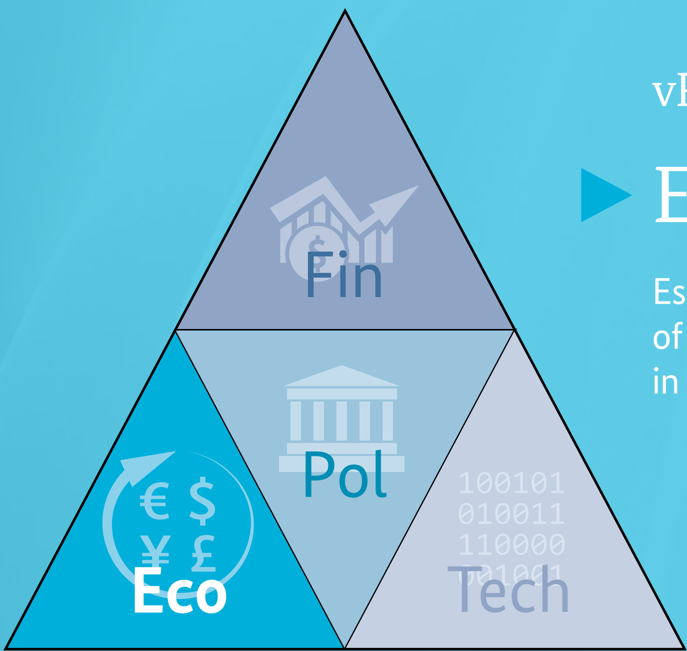

vRE Discussion Series – Paper # 02

ECONOMICS

Estimating the Operational Benefits of Growing PV and Wind Shares in National Power Grids

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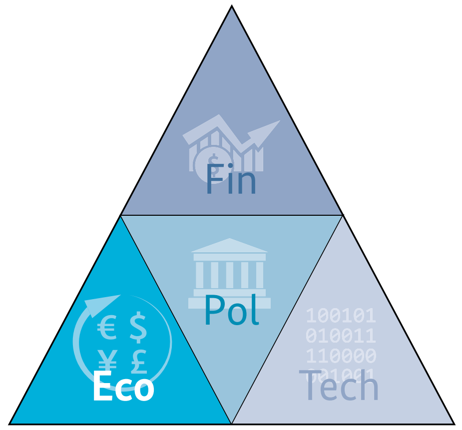

The GIZ TechCoop vRE Programme

Over the past decade, a “1st wave” of National Subsidy Programmes for variable/ fluctuating Renewable Energies (vRE) has (i) led to impressive growth in global cumulative installed capacity of wind and PV power and (ii) dramatic RE cost reductions. However, due to their typical “technology push” focus, most of these **1st wave national vRE programmes have not aimed at achieving an economically optimal pathway for national wind and PV development over time**. Naturally, this has led to suboptimal national RE deployment, resulting in (i) unnecessary losses of Government budget and credibility (subsidy schemes were too expensive or too slow, RE technologies were scaled up too early or applied at the wrong network nodes, lack of planning resulted in avoidable transmission losses or dispatch problems), and/or (ii) excessive private sector profits and/or massive insolvency waves after subsidy-driven vRE bubbles. None of this is intrinsic to vRE technologies or economics: it was simply ill-advised planning.

Increasingly, OECD and non-OECD Governments want to move beyond simple vRE technology-push policies, and shift to a new, 2nd wave of optimized national vRE pathways, by applying the same fundamental economic, financial and political goal functions that are used successfully for standard power system planning. To this end, vRE need to be analyzed as an INTEGRAL part of the national energy system and its growth in time and space, by applying methods which readily fit the toolkit already used by dispatchers, regulators and utilities.

Integrated vRE National Masterplans do not exist yet, though it is pretty clear what they would have to accomplish (IEA 2014, SMUD 2013). This has several causes, such as: (i) the inherent fluctuating character of vRE (wind and PV feed-in depends strongly on sunshine and wind availability at any given moment) poses a set of specific power planning and dispatch problems to established sector agents (dispatch, regulator, utilities) which may seem daunting initially (yet, a closer look reveals that they can be handled easily by these players with their existing processes, with a modest amount of training); (ii) existing studies have often focused on OECD countries and their results are not readily transferrable to GIZ partner countries (where grids can be weaker and demand grows faster and hydro can play a more positive role in vRE development); and (iii) few studies focus on pragmatic incremental steps based on the real-life generation mix, transmission system and fixed short-term capacity planning of specific countries (most look at long term vRE targets including smart storage >2030 instead, thus providing little guidance to pragmatic policy makers).

The GIZ vRE Discussion Series

Under the “vRE Discussion Series” we will continuously put forth emerging results and issues of special interest to GIZ partners, along the 4 main fields of our work: vRE policy, economics, finance and technology issues. As the series’ title indicates, these are often based on work in progress, and we strongly encourage suggestions and ideas by mail to the contact below.

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ECONOMICS

Estimating the Operational Benefits of Growing PV and Wind Shares in National Power Grids

An empirical study based on real-life power systems and dispatch in Argentina, Bolivia, Ecuador and El Salvador

W. Teplitz, K. Reiche, E. Durand - iiDevelopment.
vRE Discussion Paper. Please mail questions or comments to reiche@iidev.de[1]

1. In spite of the current shale gas bonanza, many Developing Countries consider increased shares of variable Renewable Energies (vRE) such as Solar Photovoltaics (PV) or Wind Power in their national energy mix, in light of growing generation shortages, falling vRE equipment costs and environmental considerations. While the decline of vRE generation costs towards so called "grid parity" and the resulting expected long-term increase in generation shares (especially in sunbelt countries) have been the subject of recent grey literature as well as some academic publications, there is still a striking lack of solid estimates regarding the "hard facts" of vRE penetration benefits: that is, the actual costs and benefits from integrating significant (sic) shares of PV and/or Wind into the real-life generation matrix of specific countries. For Developing Countries, this gap is even wider [Cochran 2013]. Accordingly, recent literature calls for more sophisticated analysis of vRE economic benefits, for a broader range of real-life scenarios [RMI 2013, BNEF 2012].

2. We have addressed this gap in empirical research by calculating the **"Operational Benefits" (OpBen)** that would result from feeding significant shares of vRE electricity generation into the real-life power mix of Argentina, Bolivia, Ecuador and El Salvador, by modelling optimal hourly dispatch with and without vRE. Operational benefits measure short-run cost savings conditional on a given thermal plant mix. In the long-run, adjustments in the size and composition of thermal plants may reduce these savings, but only at the margin.

3. Operational Benefits (that is, saved fuel and power plant start-up costs at optimal unit commitment and dispatch) are a good, pragmatic proxy for the total economic benefits (as a complementary information to the standard methods for long-term sector planning), because:

    a. they allow to derive unusually exact estimates of vRE "minimum economic benefits" (low error margins), thus offering a simple yet solid base for vRE policy planning;

    b. they are similar to the "avoided cost" approaches commonly used in standard Economic Analysis and therefore easy to comprehend;

    c. they evolve around standard power plant dispatch optimization (including spinning reserve constraints) and can therefore be easily understood and used by TSO; and

    d. they can be calculated with relatively modest simulation efforts (in terms of CPU time, once a suitable optimization algorithm has been coded and tested) and therefore allow scenario analysis for many vRE shares, fuel prices and sector development alternatives.

4. Using data from the respective dispatch centers, we have simulated the optimal dispatch for the real-life generation matrix of four case countries in Latin America (Argentina, Bolivia, Ecuador, El Salvador) with hourly resolution, (A) for vRE shares from one to ten percent of annual electricity demand (corresponding to about 2-40% installed national wind and PV capacity, depending on spatial distribution of local RE resources), and (B) assuming fossil fuel prices ranging from half of the present country cost to their double (spanning a total range of about 50-250 US$/BBL in equivalent fuel prices and a corresponding span of gas prices).

5. Our forthcoming simulation results indicate that:

    a. The Operational vRE Benefits we have calculated for four Latin American power systems **are roughly the double of comparable benefits that have been estimated by previous studies** [RMI 2013]. This is largely thanks to existing hydro generation: where available, hydro storage basically "boosts" vRE benefits in today's generation mix, by allowing to shift PV and wind generation to the evening demand peaks, much like battery storage would in future smart grids.

    b. Operational benefits in our base case scenario (fuel price around 100 $/bbl and 5% vRE share) range from about **10 to 15 US cents per kWh** (or 100 to 150 USD/MWh) for the four countries we have studied, comparing well to 2013 PV and wind LCOE in Latin America.[2]

    c. While vRE Operational Benefits naturally tend to grow with fuel price and fall with vRE share, they do so in surprisingly counter-intuitive ways – for instance, **Operational Benefits can actually increase with vRE share** in some cases, and they drop less than expected at vRE shares up to 10% of annual electricity generation.

    d. Full consideration of system stability (by way of additional required spinning reserves for each MWp of injected vRE) has a surprisingly low effect on Operational Benefits. This is because actual spinning reserves under optimal dispatch (including stored and dispatchable hydro resources) are often well above required spinning reserves anyway.

    e. The calculation of vRE Operational Benefits is a straightforward, complementary approach to producing solid data for short-term and medium-term power sector planning for growing vRE shares.

[1] *This paper is based on a presentation to a series of international donors during the 1st giz vRE road-show in 2013.*

[2] *To this "main benefit" via avoided cost, additional benefits (such as hedging against price volatility [Awerbruch 2007 in lieu of many]) and system costs (such as grid stabilization [World Bank 2013]) obviously have to be added and contrasted with average vRE LCOE in order to estimate EIRR. While these "secondary" system costs and benefits are typically more difficult to calculate, they are also significantly smaller than the operational benefits.*

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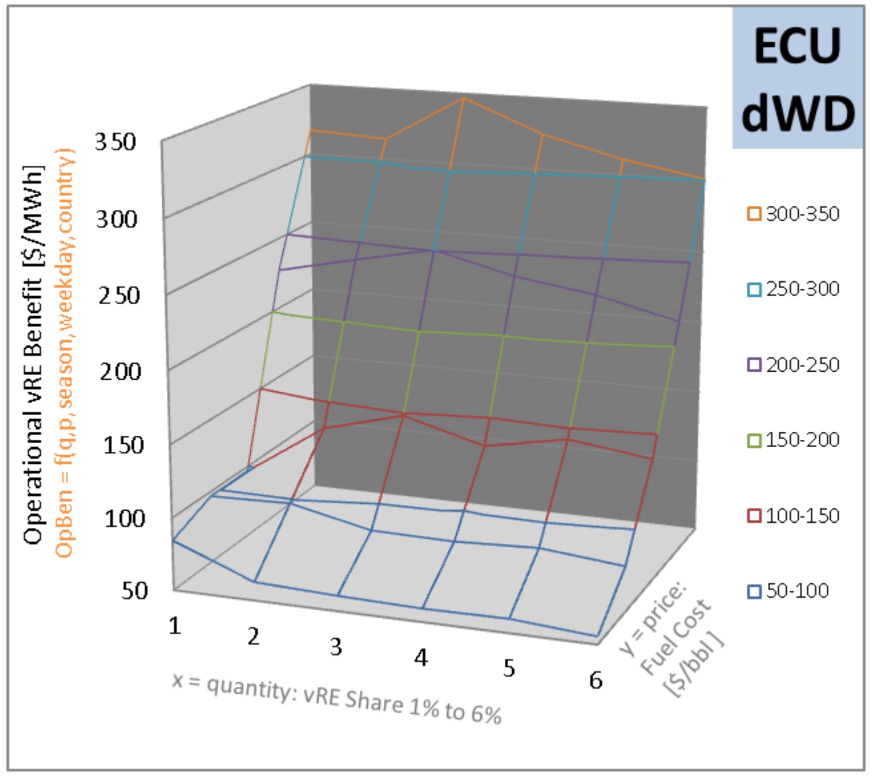

Figure 1: The Operational Benefits of adding 1 to 6 percent annual vRE generation to the national generation mix of Ecuador on a wet season weekday, for fuel prices from 50 to 250 $/bbl.

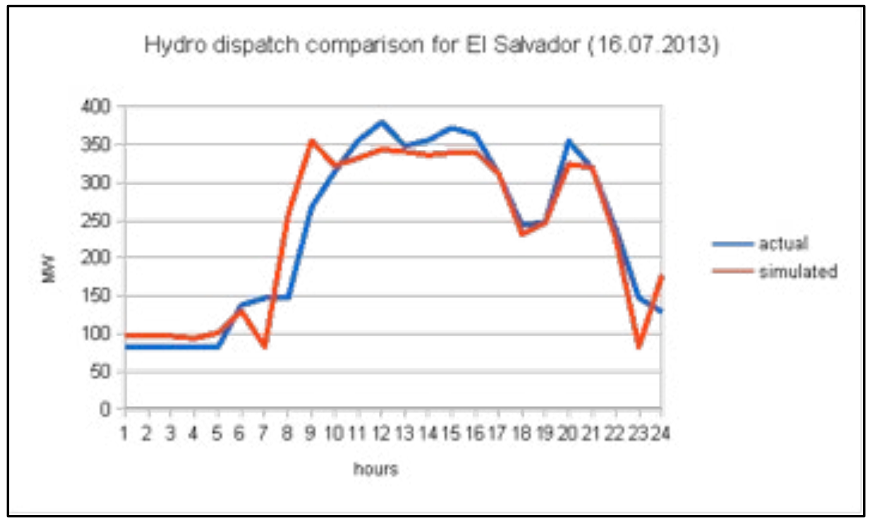

Figure 2: We have tested our model by comparing simulated dispatch (red line) with real dispatch (as calculated and run by TSO) for the actual demand curve of single days. The graphs show the residual hydro dispatch. Thermal dispatch fits just as well.

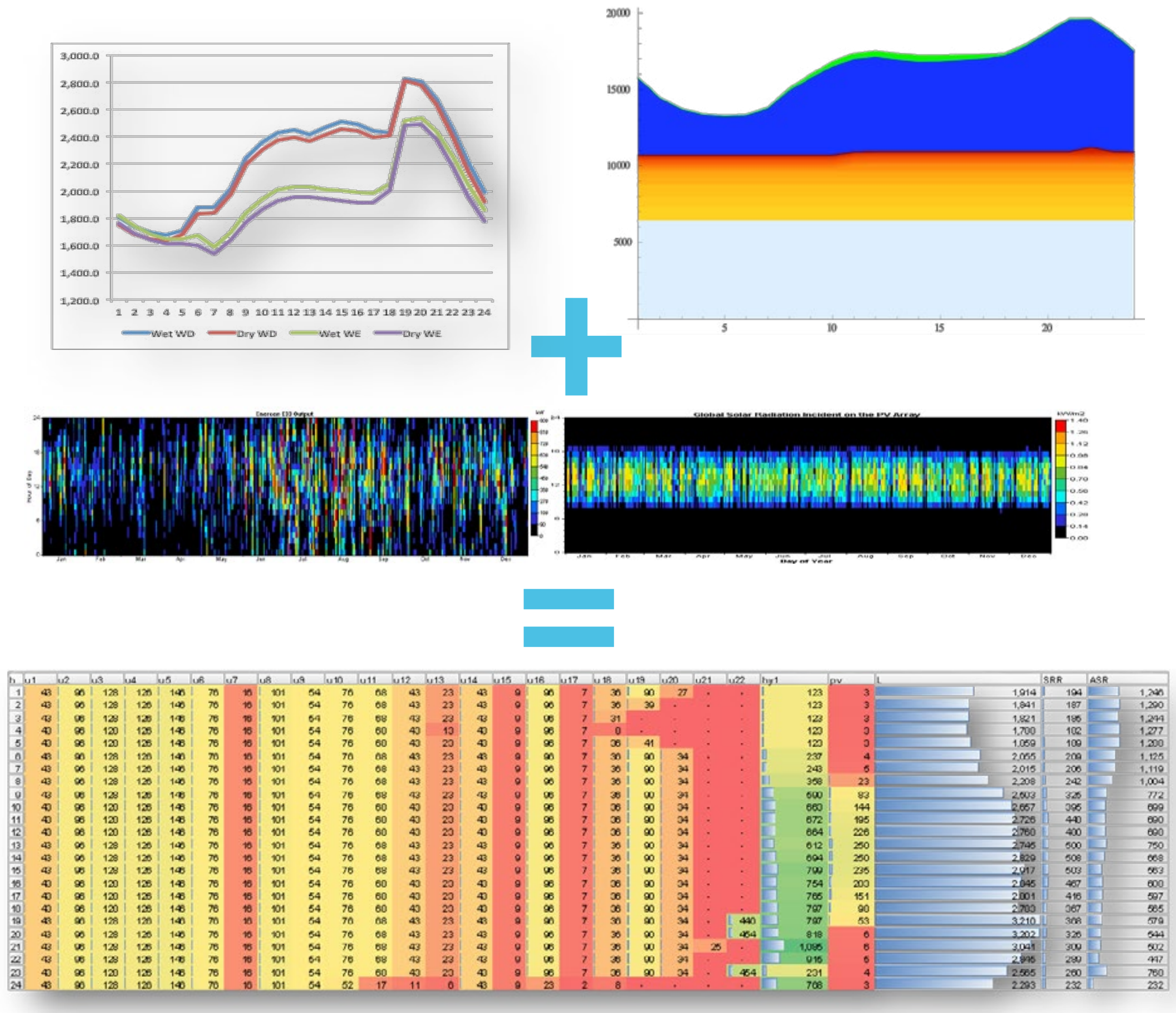

Figure 3: The basic steps of calculating Operational Benefits is simple: (i) IN step one, we simulate optimal dispatch at given load curves, generation matrix (that is, unit costs and start-up costs of each power plant in country N) and hydro constraints (seasonal water availability) as well as national spinning reserve requirements; (ii) In step two, we redo the same after adding x% PV and wind generation (based on country-typical hourly patterns for both, based on simulation by professional software such as PVSys and WASP, or similar) to the generation matrix; (iii) then operational benefits are equal to the avoided costs from step one to step two: iii=i-ii. These three steps are repeated about 2000 times per country, to analyze the effect on benefits of (a) vRE share, (b) fuel price, and (c) the time-dependence of load curve and RE patterns.

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