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First International Renewable Energy Storage Conference (IRES I)
Towards energy autonomy with the storage of Renewable Energies
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Management of Renewable Energies and Storage Systems – The Swiss Case

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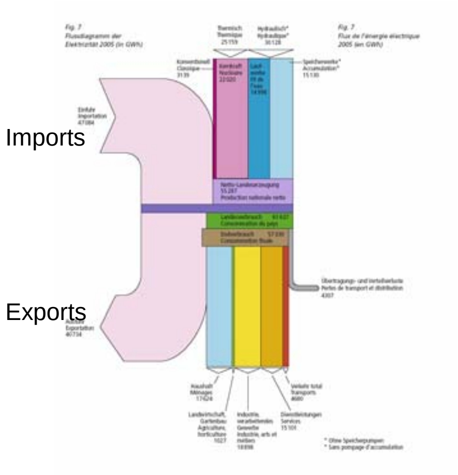
(November 2006 update version) / (Figure 1)

Content

1. Introduction: Characteristics of the Swiss electricity system

Power management and storage are important tools on the way to an energy system based 100 percent on renewable energies. Switzerland was a pioneer in electricity generation and is a European leader in power storage, management, and cross-border trading of electricity. Its electricity imports and exports almost equal its national power consumption.[1]

Swiss Imports and Exports of electricity



- Imports and exports almost equal internal power consumption
- Transit nation
- vast claims on French nuclear stations: contracts or assets for 2,5 GW of (non dispatchable) deliveries

<u>Figure 2 Swiss electricity production, consumption and trade</u>

The country's mountains, extensive snows and glaciers, its water resources and a mature hydro technology predestine Switzerland as a core element of the Western European electric power system: for backup capacities, intra-day or seasonal power management and storage of reserve power.

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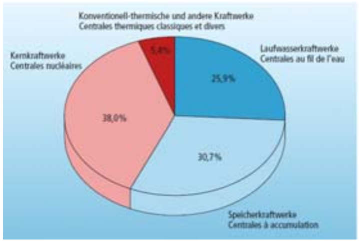
1 Data and Graphs from Schweizerische Elektrizitätsstatistik 2005

Swiss electricity production 2005



Power sources

56.6 % hydro

- •25,9% run-of-river
- •30.7% storage lakes

38.0% nuclear

5.4 % other:

(CHP/gas CHP/biomass or waste, wind, solar

Figure 3 electricity generation, market shares in Switzerland

In 2005 Switzerland derived its electricity from these major sources: 56.6 % hydro (25,9% run-of-river, 30.7% storage lakes), 38.0% nuclear, 5.4 % other (CHP/natural-gas CHP/biomass&waste, wind, solar).[2]

The use of nuclear power is contested and its replacement by new renewable energy is debated.

Switzerland: Transit, Storage, Trade (TWh)

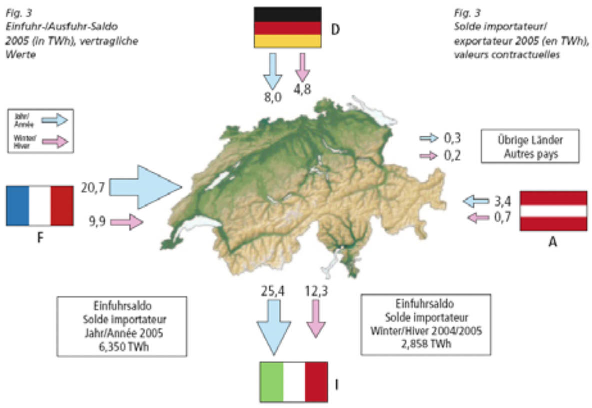


Figure 4 Swiss Electricity Imports and Exports

The power companies, mainly state-owned but without much democratic control, have large claims on French nuclear power stations (2,5 GW of delivery contracts whereof some proprietary stakes). However, Electricité de France

[2] Data and Graphs from Schweizerische Elektrizitätsstatistik 2005

(EDF) is contractually permitted to deliver power to Switzerland to a large extent in periods of its own choice.[3]

Figure 5 Swiss hydro power capacity and production[4]

		rated maximal power MW					medium production GWh			
Canton	number of plants	run of river	storage power station	pump storage station	circular storage station[5]	Total	run of river	storage power station	pump storage station	Total
Zürich	13	65.86		48.4		114.26	443.61		101.2	544.81
Bern	61	268.38	614.73	53	311.00	1'247.10	1'391.51	1'718.07	35.2	3'144.78
Luzern	8	7.65				7.65	48.21			48.21
Uri	20	283.37	204.66			488.03	1'139.70	383.22		1'522.92
Schwyz	14	62.36	48	118.08		228.44	234.72	60	181.44	476.16
Obwalden	11	35.53	77.76			113.29	152.19	146.74		298.93
Nidwalden	5	28.98	14.14			43.12	120.01	31.06		151.07
Glarus	29	91.49	379.3			470.79	353.87	531.7		885.57
Zug	6	7.4		14.52		21.92	37.21		30.36	67.57
Freiburg	12	48.44	124.32	93.94		266.7	154.06	388.44	72.8	615.3
Solothurn	8	87.3				87.3	538.46			538.46
Basel-Stadt		46.66				46.66	274.21			274.21
Basel-Landschaft	10	53.59				53.59	303			303
Schaffhausen	4	35.7			5	40.7	254.66			254.66
Appenzell A.Rh.	3	8.9				8.9	22.98			22.98
Appenzell I.Rh.	1	1.37	2.5			3.87	3.06	7.7		10.76
St.Gallen	44	57.35	88.6	274.3		420.25	237.71	181.72	175.9	595.33
Graubünden	82	560.31	1'904.38	172.5		2'637.19	2'161.77	5'401.54	303	7'866.31
Aargau	22	475.52				475.52	2'969.56			2'969.56
Thurgau	8	8.53				8.53	50.17			50.17
Tessin	30	275.07	916.71	212		1'403.78	933.85	2'447.24	122.8	3'503.89
Waadt	21	147.87	28.97	146.06		322.9	656.52	36.39	113.2	806.11
Wallis	87	814.6	3'570.13	250.65		4'635.38	3'185.00	5'925.04	438.53	9'548.57
Neuenburg	11	33.45				33.45	139.23			139.23
Genf	3	128.47				128.47	621.66			621.66
Jura	3	6.32				6.32	32.8			32.8
Switzerland	516	3'640.46	7'974.20	1'383.45	316	13'314.11	16'459.75	17'258.85	1'574.43	35'293.03
Medium capacity factor							*0.523*	*0.251*	*0.13*	*0.307*

So, up to now, the French and Swiss nuclear power industry is dependent on the renewable hydro system and not the other way around! (Nuclear) France and (coal oriented) Germany profit from the Swiss hydro storage system. And so does Italy which for decades imported most of the French and Swiss net overproduction. Overcapacities of electric power generation was a major symptom since the 1970es and led to a wasteful consumption of power (inefficient electrical heating, growing stand-by-losses, absence of efficiency policy).

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[3] The French producers have the right to deliver no power whatever for a number of days per year (1-2 months or so) at times of their choosing. So, this makes French nuclear power no more reliable as a back-up source than wind power.

[4] Data from Bundesamt für Energie **http://www.bfe.admin.ch/themen/00490/00491/index.html?lang=de&dossier_id=01049**

[5] So called Umlaufwerk, no natural inflow of water

Two different
Hydro storage systems

1. Passive without pumping
   – Delivery in accordance to time schedules
   – use of storage lake's natural inflow
   – Side-effect: Anti-Inundation Management

- Active, but with energy loss
   – Upstream pumping/downstream draining using natural or artificial basins
   – Loss of some 20% of energy for pumping

Figure 6

The system of electricity storage with hydro power works in either of two modes:

- Lossless power storage without pumping.
- Pumped power storage that, however, entails losses.

Lossless power management works by relying solely on the natural flow into, and the managed flow out of, storage lakes.

Pumped-storage, on the other hand, relies on the active management of the volume and timing of the storage reservoirs' out- *and in*-flows.

These two systems allow the matching of electricity generation to the daily and seasonal load variations, albeit with pumping at the loss of energy spent in the uphill movement of water (loss of some 20% of pump-stored electricity).

Full load hours
of some Swiss hydro plants

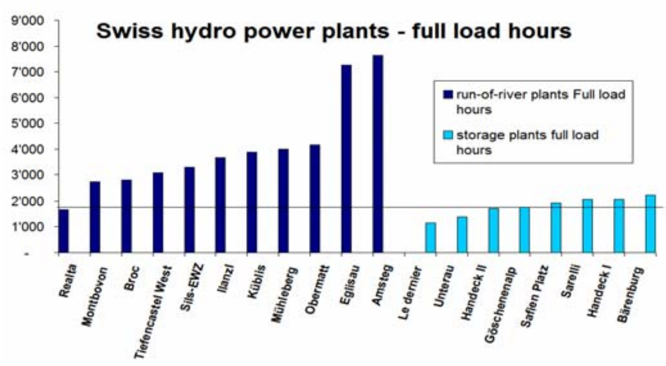


Figure 7 yearly full load hours of hydro plants

When we examine the production statistics of Swiss hydro power plants, here mainly from the Rhine[6] river, we discover a couple of interesting facts:

First, some *run-of-river plants* show quite low outputs in terms of full load hours (FLH). They have no more full-load-hours than, say, offshore-wind-farms (2800-4500 FLH) or even onshore wind farms (1000-2500 FLH). And the yearly variance of hydro production might sometimes be higher than with wind or solar! River flow is subject to substantial fluctuations due to events upstream, including rainfall, snow or glacier melt and storage management, that all are reflected in the plants' power output.

Second, you note that many hydro *storage facilities* work even for less time than run-of-river plants – just between 1000 to 3000 FLH a year in terms of net production.

[6] production data is not representative for the whole hydro park! Source: Verband Schweizerischer Elektrizitätswerke, Bulletin VSE/SEV 2/96, S. 11-13

Capacity, Power generation and Full Load Hours of Swiss hydro

Swiss Hydro Power Plants			
number of plants > 300kW	516		
Capacities	MW		
run of river	3'640		
storage power station	7'974		
pump storage station	1'383		
pure circular storage station (Umlaufwerk)	316		
Total capacity MW	13'314		
		medium capacity factor (Full load hours/year)	full load hours/ year
medium yearly production	GWh		
run of river	16'460	*0.523*	4521
storage power station	17'259	*0.251*	2164
pump storage station	1'574	*0.13*	1138
Total	35'293	*0.307*	

Figure 8

Medium capacity factor of storage facilities is just 0,251 (2164 FLH/y) and run of river plants have an average capacity use of 0,52 (4521 FLH/y). Pump storage is used just for 1138 hours of full capacity (capacity factor of 0,13).

Most of the seasonal storage plants originally were built for storage of summer snow-melts and rainfalls in order to accommodate the national system's peak loads then customarily occurring in winter.

Storage was a seasonal affair with huge complexes (left)

New projects rather modify existing facilities. Capacity additions often are invisible constructions underneath. (see right side)

Figure 9

It is important to know that to ensure winter delivery a big number of investments were done at a cost that was much higher at its time than the cost of, say, new wind power capacities form Northern Europe today.

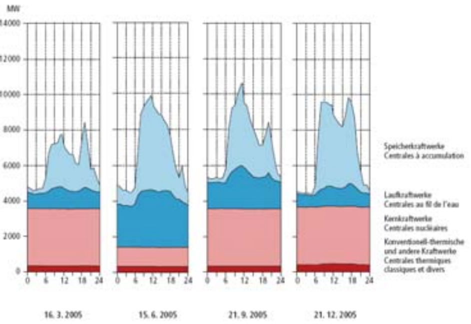
In fact both facilities – wind power and hydro storage – serve as a winter source of electricity. hydro capacities have an additional value due to their higher disposability. But it is an open question if the very big storage facilities would be built again today.

Wind power from Northern Europe is a cheaper source of bulk power with production peak in winters time, so the hydro facilities for seasonal storage might find a new role in the future within the European electricity system.

With more wind and solar in the European grid, intra-day power management and peak reserve for weekly uses may be a much better deal for hydro systems than seasonal storage of water that passes the turbine just once a year.

Intra-day and weekly power management does not need the same super huge water storages though as seasonal management used to. There might be a transition to a leaner hydro power management – with much more short time capacity or less stored water.

Production curve on third
Wednesdays of months 3/6/9/12 (2005)



<u>Figure 10 Daily Swiss electricity production</u>

Production statistics reveal that nowadays a lot of storage is drained during the day time in summer rather than in winter time, particularly for exports.[7] This in its extent is a recent phenomenon, influenced by trade expansion and ris-

[7] See Figure 10 also

ing electricity prices in the emerging European electricity market.

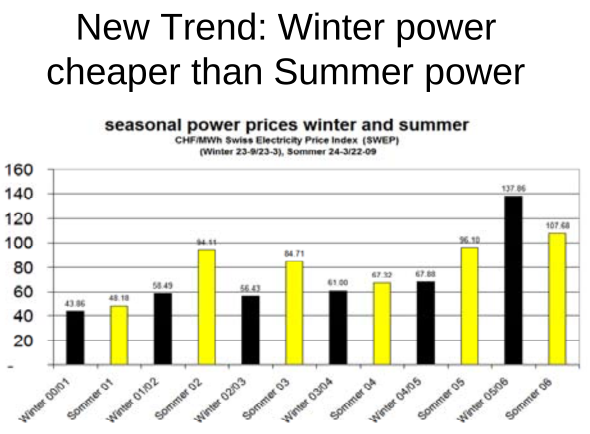


Figure 11 Average spot market Prices winter and summer

We generally have more volatility in electricity prices today than before. And we have a shift for peak load demand from winter to summer's time which is reflected in higher summer prices.[8]

These trends are important for the role and the dimensioning of Swiss storage and power capacities: It could mean that from an economic point of view it no longer is so desirable to save the summer water flow for meeting power demand in winter. It is more attractive to "sell the snow-melt" right away when it occurs.

By doing that, Swiss power managers face some difficult decisions: should they sell summer water for a better price to the European market with a risk of scarcity in winter? Or should they keep the water stored and follow a no-risk-no-profit-strategy?

If we were going to have generally cheaper winter power – due to additional wind capacities and CHP – could it be that our huge seasonal storage facilities – some as big as 600 million m^3 – might be unnecessary for seasonal storage?

What are we going to do with then? Here, the power management demand for more wind power will comes into play.

[8] Data from SWEP. There are many reasons fort his: higher temperatures in winter, better insulation, additonal winter production by CHP, natural gas and wind power and ever more air conditioning during heat days of summer time.

Electricity prices SWEP

- Rising prices in general
- Rising differences day-to-day

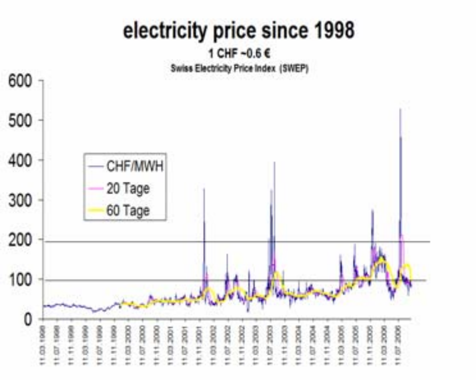


Figure 12 Swiss Electricity Price Index (SWEP)

The price data from the Swiss Electricity Price Index (SWEP)[9] show that:

- Price levels have generally risen due to growing demand and some times due to a scarce reserve capacity in Europe.
- Day-to-day and intra-day price differences are expanding as well compared to the nineties.

In 2005 at certain hours the Swiss electricity suppliers have got more than 0.50 Swiss Francs for one kWh [some 30 €C./kWh] when they opened the spigots. They could real-ize, on such days, a profit margin of more than 1000 %.

In comparison to this, the mean buyer's price (mostly base load power) from the European market was 0.047 SFr./kWh[10] (0.03 €C./kWh). Some of the electricity for the pump storage facilities is even delivered for free. For these base load plants it is cheaper to send power to Switzerland than to change capacity levels!

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[9] Data: Swiss Electricity Price Index (SWEP), http://www.egl.ch/int/ch/de/markt/swep/aktuell.3.CsvFile.csv?hc1=Datum&hc2=CHF&hc3=Tage

[10] Bundesamt für Energie: Schweizerische Elektrizitätsstatistik 2005, p. 47 Tabelle 42

In average Switzerland has a published net profit from electricity trading of more than one billion Swiss Francs, and unpublished numbers might even be higher.[11]

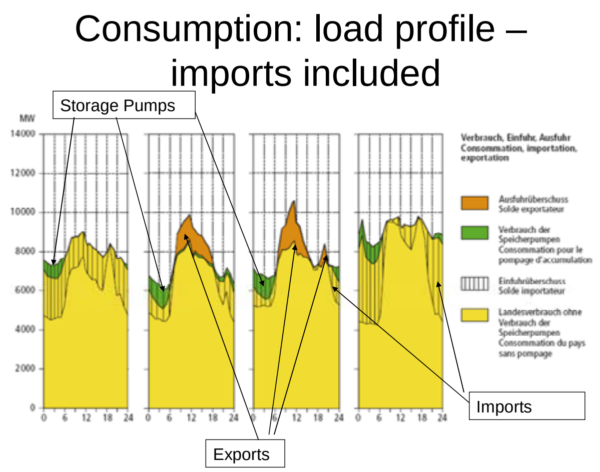

Figure 13 daily electricity load curves - consumption

we can see that during day times in the summer electric power – up to 2,5 GW – at high prices is fed to the load centers in Germany, Italy or France, and it is at night time, as the charts show, and on weekends and at winters day time when the Swiss import cheaper inflows. (A lot of this imported winter power is wasted though for inefficient use: up to 25% of electricity consumption goes for Ohmic resistance-heaters instead of heat pumps or wood pellets).

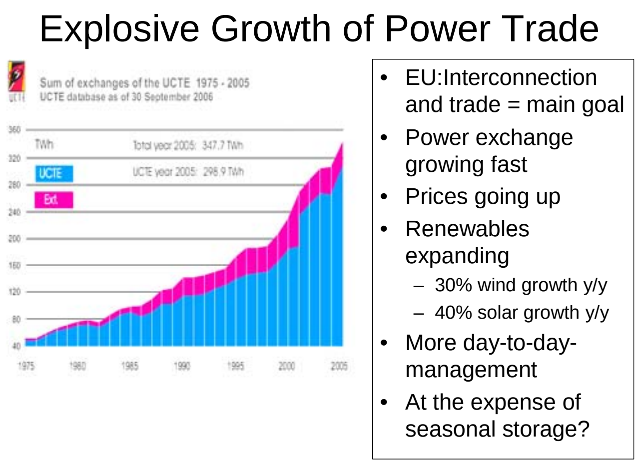

Figure 14 Power Trade UCTE

[11] Data for 2001-2004; the profit for 2005 are lower because the breakdown of the Leibstadt Nuclear Power Station for five months in 2005 led to more imports of electricity. See Bundesamt für Energie: Schweizerische Elektrizitätsstatistik 2005, p. 47 Tabelle 42

From a system point of view the integration of the European Electricity market and the fast expansion of renewable energy will bring a completely new situation and could challenge some of the old habits. So we might take a look to the *dimensions of demand for power management* in the future.

2. New Production Trends – a brief outlook for the need of power management

2.1. Renewables - better than their reputation

For many years now power companies in Switzerland and elsewhere have been and are bashing renewable energy, insisting that only central power production from nuclear, natural gas or central hydro facilities can bring security of supply. Giant power companies do everything to undermine the expansion of distributed renewable power generation or CHP that is not part of their own assets.

Still today we hear many insulting characterizations, such as Renewables being too expensive, unreliable, a cost burden, not being available when most needed (Figure 15).

Reality is different though:

- Renewables start to be renown for their cost reduction effects – eliminating the most expensive marginal producers from the power plant merit order[12] and reducing in this way the price of wholesale electricity.
- New Renewables are on a steep downward learning curve, with yearly cost reductions over the prior year's installations between 3-4% for wind power[13] and 5-8% for photovoltaics[14].
- the primary energy of renewable energy is free due to natural flows, and beside the user cost of "earning" there is no fuel price risk or volatility in the price.
- Renewable energy delivers endless, reliable earnings, available in all places of the world, but some of them with a variable, seasonal power profile that needs to be managed
- Renewable sources are so huge that they can satisfy the human demand for energy many thousand times; in the long term there is no crowding out of prices due to growing demand.

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[12] Sven Bode, Helmuth Groscurth: Zur Wirkung des EEG auf den „Strompreis" HWWA DISCUSSION PAPER 348, ISSN 1616-4814 http://www.wind-energie.de/fileadmin/dokumente/Themen_A-Z/Kosten/HWWA_EEG_drueckt_Strompreis.pdf

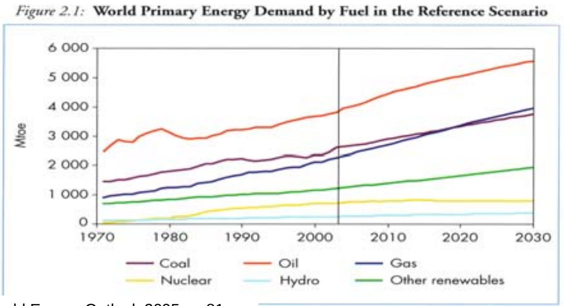
[13] T. Neumann, C. Ender, J. P. Molly: Studie zur aktuellen Kostensituation der Windenergienutzung in Deutschland 2002, DEWI Magazin Nr. 21, August 2002

[14] The feed in tariff of photovoltaic power from open land based facilities underlies a yearly nominal reduction of 6.5% which in real terms equals some 8% a year.

- Renewable peak load is available: hydro, biomass, biogas; renewable energy systems such as geothermal and run-of-river hydro are able to deliver base load power.
- Interconnection to a large extent can smooth out variability of solar or wind power; we should remember that nuclear and coal do not follow daily or seasonal load curves either![15]

But the negative arguments in the energy discussion persist and there is a number of governmental bodies such as the International Energy Agency that keep telling us for years that Renewables can and will not show significant growth within the power business.[16]

IEA World Energy Outlook 2005:
fossil fuel as an endless, renewable energy



World Energy Outlook 2005, p. 81

<u>Figure 16 IEA: World Energy Demand</u>

It is these pretty pictures from the IEA which are replicated by mainstream media and government officials in a predominant uncritical manner. The IEA's gospel proclaims the steady rise of oil, gas and coal consumption. They cannot, or do not want to, reckon with the coming event of peak oil or wrong reserve statistics, the visible shortage of natural gas in North America, the uranium price hike and environmental risks of fossil and nuclear power sources.

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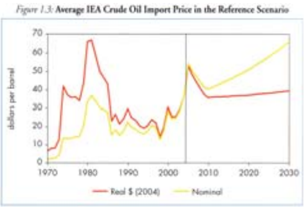
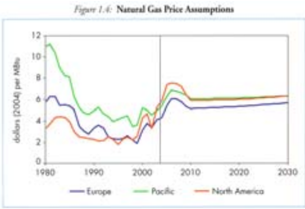
[15] For nuclear this more and more clear when loads must have been reduced during very hot summer temperatures for lack of cooling water, when loads were at maximum.

[16] IEA rose its expectation for renewables from 14 to 16 % by 2030, but gives no notice to the strong growth of wind and solar industries, see **http://www.worldenergyoutlook.org/2006.asp**

….at low prices for ever: oil at 35 $ and
natural gas at 5-6 $ MBtu !!





Source: IEA World Energy Outlook 2005, p.65 and p. 66

<u>Figure 17 IEA: Energy Prices, outlook</u>

The ever-more-ever-cheaper-ideology is reflected in the IEA price outlook. In terms of future prices the IEA published fantasies about $35/barrel oil and equivalently-priced gas even in 2005, despite a dramatically different reality with oil futures at around 60-70$/barrel and natural gas futures equally that much higher.

The mother of invention: USGS and EIA
EIA: Energy Information Agency, US-DOE

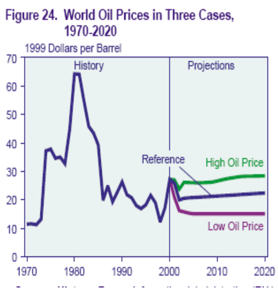
2001 Price Forecast

Source

"International Energy Outlook 2001 March 2001

Energy Information Administration, Office of Integrated Analysis and Forecasting, U.S. Department of Energy Washington, DC 20585

This report was prepared by the Energy Information Administration, the independent statistical and analytical agency within the Department of Energy."



<u>Figure 18 EIA: Energy Prices, Outlook 2001</u>

Just a few years earlier the outlooks of this kind of government think tank was even worse: In 2001 it pegged the future "low" and "high" prices of oil at $10 and at $29/barrel until 2030.

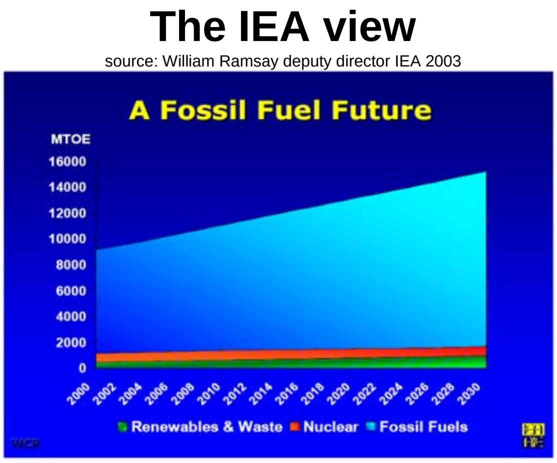


Figure 19 William Ramsay's World

This picture shows the view of the American IEA deputy director William Ramsay who came to Berne, the capital of Switzerland, to tell the Parliament Committee on Energy that investments and feed in tariffs for renewable energy should be abolished.[17]

The IEA seems perfectly unwilling to get to know the positive dynamics mentioned of renewable energies and it issued absurd misjudgments on the prospects of wind power, as an example: In its World Energy Outlook of 1998 it predicted wind power capacity to grow to 42 GW by 2020.[18]

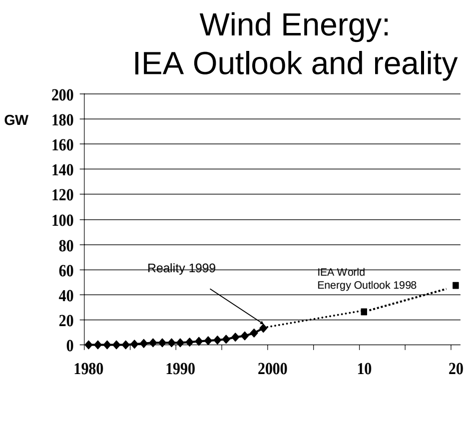


Figure 20 IEA and Wind Power

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[17] For a more in depth critique of IEA see Rudolf Rechsteiner: "Parliamentarians and the Energy conflict" http://www.rechsteiner-basel.ch/download.cfm?ID=150

[18] My thanks go to Werner Zittel from LBST, Munich, who first commented the misleading IEA prospects

It was Greenpeace who in 1999 predicted that by 2020 wind power will contribute 10 percent of world electricity and will exceed nuclear production:

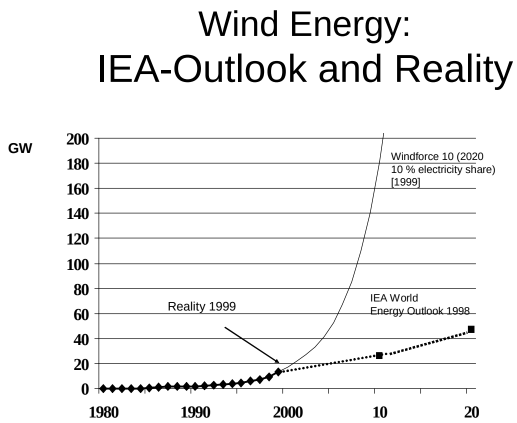

Figure 21 IEA and Wind Power

Apparently recognizing the foolishness of earlier predictions, the IEA in its 2002 WEO revised its forecasts from 40 GW to 100 GW wind power by 2020:

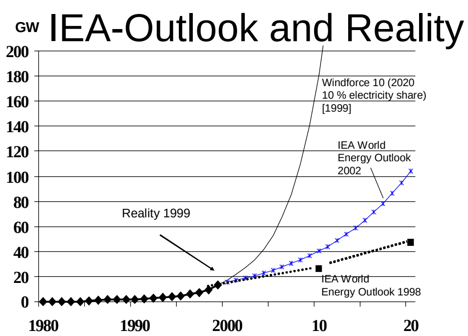

Figure 22 IEA and Wind Power

But again they were missing the point; because IEA apparently does not practice realistic resource- and cost-assessments or because they are politically biased declaring Renewables to be a "no-go", the IEA again was perfectly unable to reveal the significance of Renewables' success.

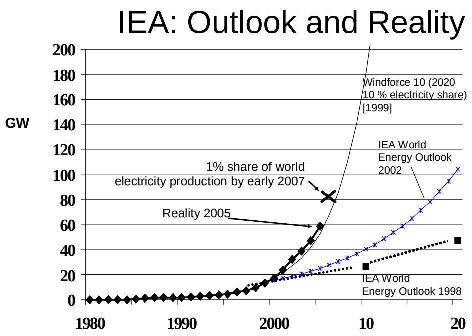

Figure 23 IEA and Wind Power

The IEA revisions introduced in 2002 and thereafter were welcome but still fell far short of reality. Wind power is growing even more dynamically than suggested in the Greenpeace vision “wind force 10”.

We will well have at least 75 GW by the end of this year [2006] and 100 GW by early 2008, within some 45% of the time frame envisioned by the IEA in 1998.

2.2. Reasons for Growth

To judge the real significance of Renewables such as wind and solar, we have to analyze the success of wind power as a model case.

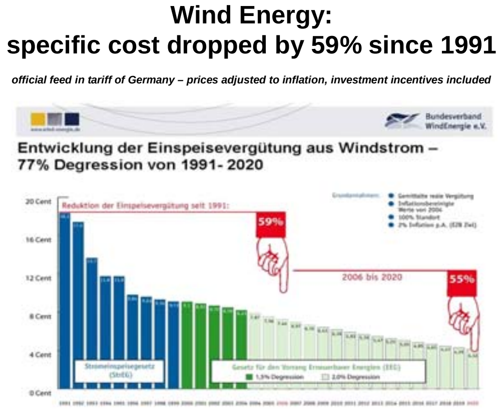

Figure 24 Cost of Wind Power 1990-2006

There are many reasons for the successful market penetration of wind power.

One is permanent cost reduction. In 1990 wind power feed in tariffs[19] were three to five times higher than the price of power from old coal power stations.

Today we find two sorts of cost reductions: reduction of investment cost per kW and higher productivity of installed MW capacity, due to better technology.

Learning Curve of Wind power

specific investment cost to produce 1 kWh per year
dropped from 0,80 to 0.38 €/kWh/a
source: BWE/ISET 2006

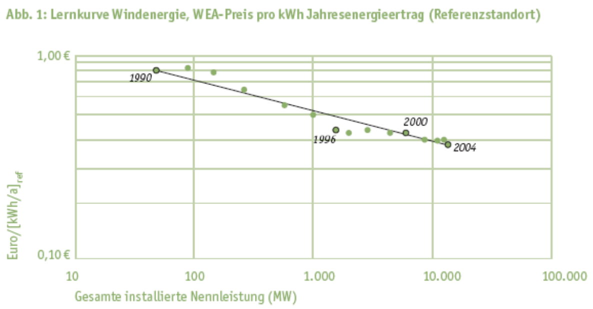

Figure 25 Specific Cost of Wind Power

This trend resulted in an investment cost reduction from 0.80 €/kWh/year to 0.38 €/kWh/year in German Reference places.[20]

The strong demand worldwide for new power plants changed the habits to view wind power. Price comparison now are done between new plants, between new wind and new coal plants, between new wind and new nuclear or gas power, and the crooked comparisons of new wind with old coal or nuclear plants whose investments have been written off, have no more importance. New wind power now is more attractive than before, when we had an oversold buyers market in the power generation business. In many re-

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[19] In the kWh cost figures included are investment subsidies launched in Germany as part of a broad program (Marktanreizprogramme). Cp. BWE **http://www.wind-energie.de/de/publikationen/folien-sammlung/**

[20] „Vergleicht man nun die Jahreskosten des Stromertrags von 1990 mit denen von 2004, so beträgt der Kostenrückgang 53 Prozent, von 0,80 auf 0,38 Euro pro Kilowattstunde…. Der Jahresertrag ist hier gleich dem Ertrag am Referenzstandort gemäß EEG. Am Referenzstandort herrscht in 30 Meter Höhe eine mittlere Jahreswindgeschwindigkeit von 5,5 m/s. Eine 1,5-MW-Anlage erzeugt bei einer Turmhöhe von 100 Metern am Referenzstandort etwa 4,5 Mio. kWh pro Jahr, genug für 2.000 Haushalte."

gions of the world, wind power is competitive with new coal-fired and even more so with nuclear plants, and cost reduction will continue in the long run (in five years time or so), when ramping up production capacities will be achieved.

There are many more structural and economic arguments that work in favor of wind power and other Renewables:

Why can renewables succeed?

Renewables market development

- No cost for primary energy
- Cost Reduction of turbines,higher efficiency
- Growing power demand
- No cooling water needed
- Short construction periods
- Abundant resource

Wind	Solar
– Onshore	- roofs, façades
– Offshore	- highways
– Floating turbines	- semi-deserts
	- deserts

Other markets development

- Resource conflicts (oil/gas/nuclear)
- Growing dependence from ever fewer providers
- Pollution/Global warming/ radwaste
- emission trading cost
- coal, gas and uranium prices
- No security about fuel costs
- Accidents/Terror/proliferation

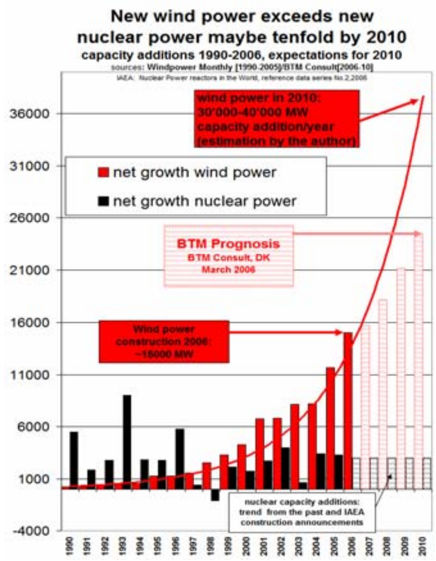
Figure 26 Success of Renewables: Reasons

Therefore I would say we can see we now come into a new stage of accelerated market penetration of renewable energy. “There are strong indications that wind power’s rate of growth is accelerating rapidly” writes Windpower Monthly[21], and this means something in a market that grew with an average yearly rate of 29% for new turbine capacity. “Total installed wind power capacity is now nearly 15’000 MW higher than this time last year” – so every fifth wind power-MW was installed during the last 12 months!

When up to now Renewables were a marginal source of energy and a marginal technology in terms of cost, it seems logical that from now on new Renewables soon will outrun

[21] Windpower Monthly October 2006 p.70

traditional technologies such as nuclear or hydro, and some have done so already on the market for new power equipment.



Average annual wind power growth 29% a year (Ø 10 years)

Wind power additions will be ten times bigger in 2010 than nuclear additions

Nuclear: average growth 2,2% (Ø 15 years)

<u>Figure 27 Wind and Nuclear Capacity 1990-2010</u>

Wind power capacity additions might be ten times bigger in 2010 than nuclear capacity additions. New annual wind-power construction exceeded nuclear in 2005 by a factor of 4; in terms of new base load it means that new wind and new nuclear were equal, but by 2010, new wind power might deliver more than four times as much energy (40'000 MW at 0.25%) than new nuclear (3000 MW at 80% medium capacity factor).

It could well be that the nuclear capacity will shrink by that time because many of these plants are old and have high safety risks. Wind power will be the power locomotive for the next ten years, and solar, geothermal and biomass follow suit.

Nevertheless there is a persistent pessimism towards Renewables throughout the main stream media such as the Financial Times (Figure 28) where Carola Hoyos, chief energy correspondent, writes: *"There is also an unprecedented rush to pioneer alternative energy resources: everything from solar and wind to waves and waste….Yet, even with expected double-digit growth, renewable energy has to increase from such a low base that it is not forecast to* *make up more than 2 per cent of the total energy mix by 2030."*[22]

Is Carola Hoyos correct? I don't think so. The future looks different – it looks bright for Renewables! We must stop to publish pessimist outlooks but it looks so that in built pessimism is not a problem of the main stream media only:

- Some of the most active NGOs in the energy field follow a certain self-censorship on future prospects, as can be seen in the Global Wind Energy Outlook 2006 where Greenpeace and the respectable Global Wind Energy Council formulate an "advanced" wind power scenario with growth rates falling from 20% (2006) to 4% (2030).[23] The numbers of this "advanced" scenario are too low right from the first year on and even more so for the long term.
- Also the forecasts of the most repudiated wind consulting company, BTM Consult, turned out to be wrong. "*Historically its five year forecasts have consistently underestimated growth. The actual rate of wind development has been 40-45% stronger than its forecasts, reveals BTM's review, based on its annual World Market Update overviews since 1995. Average growth rate over the decade has been 29.7%."*[24]

Rather than to limit ourselves to moderate or "politically correct" growth numbers we should ask about the fundamental drivers behind such a strong growth and about the future potentials for more even market penetration.

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[22] "An unsustainable outlook" by Carola Hoyos, chief energy correspondent, Financial Times October 23 2006

[23] Global Wind Energy Council and Greenpeace: Global Wind Energy Outlook 2006, p. 58
http://www.gwec.net/fileadmin/documents/Publications/GWEC_A4_0609_English.pdf

[24] 1. Windpower Monthly News Magazine, November, 2005 p.44

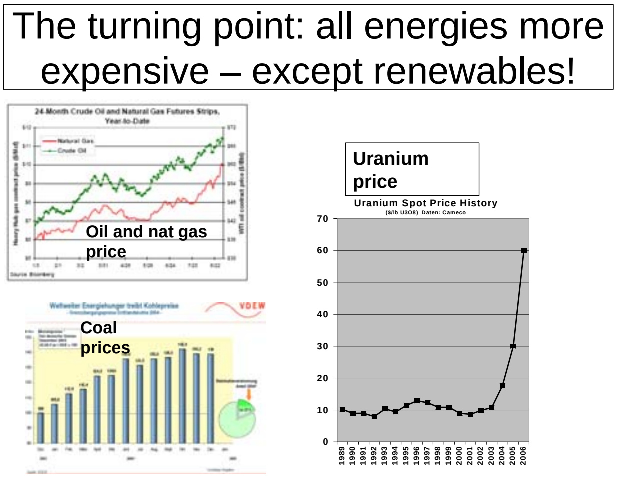


Figure 29 Prices of Non-Renewables

This strong demand for wind turbines today is driven by economic movers rather than by politics. It is prices that have all gone up for oil, gas, coal and uranium, and with CO_2-certificates another cost element will follow in favour of wind. It is the renewable sector where cost reductions go ahead despite minor price increases or volatility due to excessive demand for new capacities.

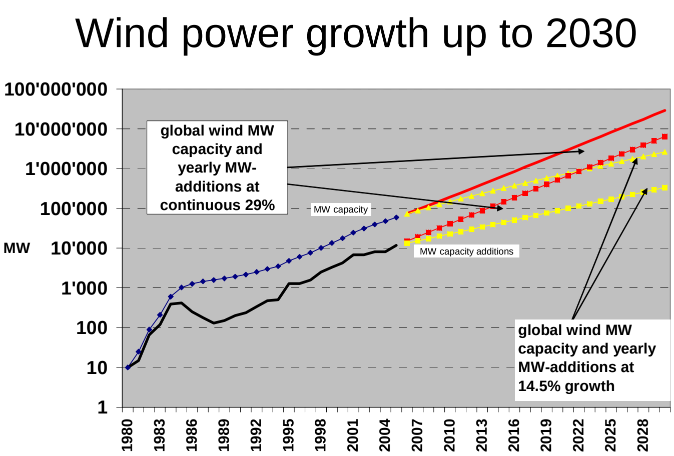


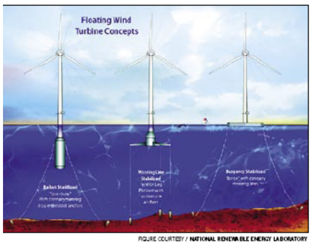
Figure 30 Wind Power Scenarios

Even in a low-growth scenario – 14.5 % yearly growth or half as much as in the last ten years – we expect to arrive at some 2600 GW of wind power by 2030, but it easily could be more (some 10'000 GW by 2025 with a continuous 29% growth rate – and reality may be somewhere within this range).

Wind power energy production in this way may exceed nuclear output some years before 2020, and wind's long-term share of the electrical power industry may arrive at more than 50% long before 2040 or so.

For this, we need new system integration elements such as High Voltage Direct Current (HVDC) lines toward less populated areas, more offshore technology and some additional innovations such as floating turbines.

Floating turbines – a new world of renewable power



"Deep-sea oil rigs inspire MIT designs for giant wind turbines"

Norsk hydro: first prototype announced for 2007

<u>Figure 31 Floating Wind Turbines</u>

Such innovations are nothing exotic because the base technology is all there – at offshore oil facilities or in existing offshore wind farms and huge turbines up to 6 MW in testing. Floating wind turbines could become another multi-billion-business for regions where low-level-sea areas are not sufficiently available, and with huge prospects for cost reductions if produced in a mass market.

Solar growth up to 2010

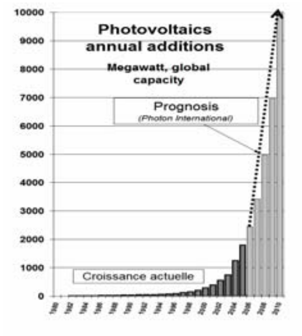


Figure 32 Photovoltaics 1990-2010

And wind is not the only candidate for fast growth; solar, geothermal and biomass technologies all are in pole positions for growth. Photovoltaics will multiply its output fivefold by 2010, says Photon International[25], a principal news magazine in the sector, and additional capacities for silicon and manufacturing will drive cost and prices down.

Wind power and solar can and will replace not only nuclear power but also a lot of coal and gas power base load plants. This trend is not new, but the velocity of change is staggering.

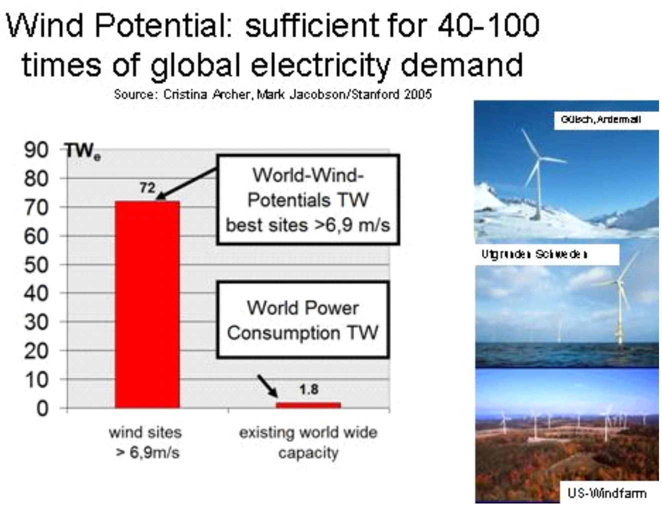


Figure 33 World Wind Resource and electricity consumption

There is no resource restriction for Renewables nor is it prohibitive cost today that could put a brake on its visible

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[25] Market expectations of Michael Rogol, Photon International 2006, div. ex.

expansion. Wind power alone could fulfill the worlds electricity needs, and other Renewables can do the same.

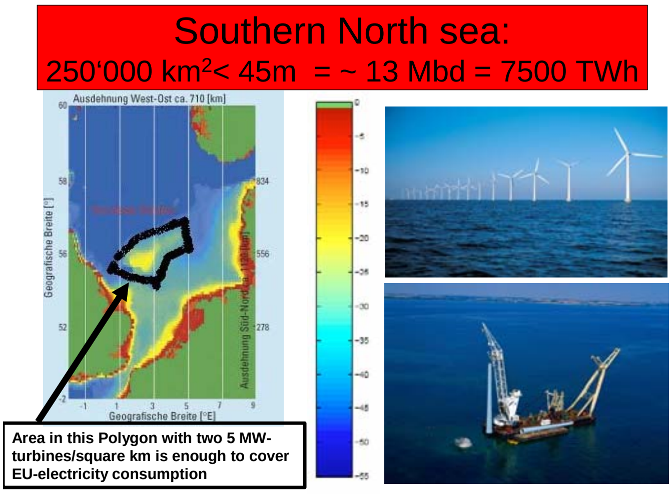

Figure 34 Wind Power North Sea

We must be aware that some 60’000 km^2 of offshore wind farms with some 2 turbines, rated at 6 MW, each square kilometer are able to deliver the complete electricity consumption of the European Union.[26] It is the inadequacies of interconnection, distribution and power management that loom as potential obstacles, and of course the restless attempts of coal and nuclear industries to stop or delay the expansion of Renewables. So-called “intermittency problems” are the workhorse objection launched by these groups. So there is a challenge. And what can we do?

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[26] See Gregor Czisch: sea bed profiles in some areas in and around Europe http://www.iset.uni-kassel.de:80/abt/w3-w/folien/Windenergie/offshoreflaechenauswahl_2.pdf

3. How to cope with variability

To cope with variability there are a number of different approaches. We have good reason for optimism to master this task.

3.1. Approach 1 put intermittency in perspective

Approach 1:
put intermittency in perspective

- Wind and solar are variable but
  - De-central, incremental load
  - smaller, easier manageable loads
  - Renewable primary energy, no fuel risk
- nuclear or gas have its own risks
  - fuel delivery
  - Domino effect of accidents: „Chernobyl in New York“ (by terror attack) would force nuclear down within hours
- Coal and nuclear
  - Do not follow load curves easily

Figure 35

Intermittency in the sense of a certain *Loss of Load Probability* (LOLP)[27] is not a prerequisite of renewable energy. Gas, oil, nuclear power and even coal are burdened with specific risks. Coal and nuclear power plants work best at constant loads; they do not follow the variable load curves without exacting supervisory management. Power management is necessary for all sources.

It is the net output of all wind turbines on the system or large groups of wind farms that matters. The wind does not blow continuously, yet there is little overall impact if the wind stops blowing somewhere – it is always blowing somewhere else. Thus, wind and solar can be harnessed to provide reliable electricity even though the wind is not available 100% of the time at one particular site.[28]

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[27] See Robert Gross et al.: The Costs and Impacts of Intermittency: An assessment of the evidence on the costs and impacts of intermittent generation on the British electricity network, **http://www.ukerc.ac.uk/component/option,com_docman/task,doc_download/gid,550/**

[28] See the speech of Arthouros Zervos, EWEA president, at Brussels conference 2006
http://www.ewea.org/fileadmin/ewea_documents/documents/events/2006_grid/Arthouros_Zervos.pdf

Conventional power systems have their own risks and a more complex fuel supply and emissions situation behind.

You can call the Russian gas boycott against Ukraine in 2005/2006 a “gas intermittency”. And the Chernobyl accident was something like “nuclear intermittency”, with the existence of many plants put into question. Accidents or excessive cost of capital, fuel conditioning or waste might spell the end of this industry end sooner rather than later.

Something like a domino closure of nuclear plants happened in Japan in 2003, when falsified documents forced Tepco[29] to shut down all its 17 nuclear power plants within days.

A second accident like Chernobyl would have the same domino impact, with people forcing governments to shut down immediately and replace nuclear power as fast as possible.

“When a fossil or nuclear power plant trips off the system unexpectedly, it happens instantly and with capacities of up to a thousand MW –that is true intermittency. Variations in wind energy are smoother, because there are hundreds or thousands of units rather than a few large power stations, making it easier for the system operator to predict and manage changes in supply as they appear within the overall system”, says EWEA-president Arthouros Zervos.

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[29] Tepco Tokyo Electric Power Company

3.2. Approach 2 regulative allocation of cost burden

Approach 2
regulative reallocation of the cost burden

- each energy has its intermittency problems.
- it is a burden that must be shared by the consumers
- All aspects of security of supply must be respected

Figure 36

The goal of an emission-free, 100 % renewable energy system and the reduction of risks and pollution is a main political task. The way to go therefore cannot be solved with one instrument; we rather need a broad approach with diversified strategies. Technical, political and regulative instruments must be part of the solution.

Variability of production and consumption is a general management task common to every power system. Some solutions for the integration of Renewables are similar to those that worked well for years for nuclear or coal with their base load characteristics. But new approaches must be introduced too.

Politicians now start to realize this. The German, British and Texas governments announced very recently that transmission costs for new wind power will be paid by the system operators and the power consumers respectively rather than by the wind farmers themselves.

With this important change in interconnection rules, wind farms can be placed economically farther away from inhabited regions, they can be located where wind energy is more plentiful, such as in the North Sea and in the Texas Panhandle, and new technology with bigger potentials can go its way. These small announcements are part of an overall framework change for power regulations. More will follow! There are many new studies done on intermittency

- The German dena-Netzstudie (2005)[30]
- The EWEA report: Large Scale Integration Of Wind Energy In The European Power Supply: analysis, issues and recommendations (2006)[31]
- The Utility Wind Integration Group (UWIG) report: "Utility Wind Integration State of the Art [32]
- The IEA report Variability Of Wind Power And Other Renewables, Management options and strategies (2005)[33]

"The consensus view is that wind power impacts can be managed with proper design and operation of the system", writes the *Utility Wind Integration Group of the USA* where all utilities are represented.

3.3. Approach 3 Non-renewable energies as backup

Approach 3
Non-renewables as "additional" energies

- Let's use coal & gas as additional power
  - "lender of the last resort"
  - when other capacity management instruments are exhausted.
- Give priority to storage techniques footing on renewables
  - Hydro storage, biomass
  - Heat storage, batteries etc.

Figure 37

Some people think that we face lesser problems staying with fossil or nuclear technologies where primary energy is a natural storage.

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[30] Studie im Auftrag der Deutschen Energie-Agentur GmbH (dena): Energiewirtschaftliche Planung für die Netzintegration von Windenergie in Deutschland an Land und Offshore bis zum Jahr 2020 http://www.offshore-wind.de/media/article004593/dena-Netzstudie,%20Haupttext,%20r.pdf

[31] http://www.ewea.org/fileadmin/ewea_documents/documents/publications/grid/051215_Grid_report.pdf

[32] http://www.uwig.org/UWIGWindIntegration052006.pdf

[33] http://www.iea.org/Textbase/Papers/2005/variability.pdf

Renewable power however is derived from natural flows that must be earned “just in time”. Therefore the traditional power agents call renewable power “additional”[34].

I would like to turn this word the other way round: Lets call oil and coal additional!, lets use them at times when renewable capacities is not able to deliver.

Worldwide peak of fossil fuels is expected by 2010 or so, and delivery costs are rising. $60/barrel oil might be seen as cheap within a couple of years, and it indeed is. Oil and gas will not stay at this price; prices will get more volatile and then will rise.

A shortage of cheap uranium is also visible in the uranium market where prices rose six fold in the last five years.

Coal of course can serve as a back-up solution, something like the lender of the last resort. But you find depletion indicators even for coal, with diminishing rates of energy return in many places of the world.[35]

I am not against coal power as long as old coal plants are used only twice a year for a week or so, when ordinary back-up systems could be temporarily exhausted.

[34] Heinrich von Pierer, Siemens Chef: „So wichtig es ist, auf additive Energien zu setzen, so dürfen wir dabei die Energiesicherheit nicht aus den Augen verlieren.“ from: Die Welt 27.01.2005“

[35] “The UK coal peaked already in 1913! In the end of the 19th century the EROEI of coal mining was about 5 (18% of the coal mined was used by the coal industry itself…” see **http://www.theoildrum.com/story/2006/5/28/151733/818**

3.4. Approach 4 diversity of renewable supply

Resource	Load profile	Storage	Storage loss	Delivery on demand
Hydro free-flowing	Steady, high seasonal variance	--	--	--
Hydro storage	On demand, dependent of natural inflow	Power	--	X
Hydro pump storage	On demand, dependence of regular load inflow	Power	X	X
Geothermal	Steady base load	Heat		
Biomass and biogas, waste	On demand, dependent of natural cycles	Power or heat daily/seasonal	--	X
Wind power	Variable, lower yearly variance than water (?)	--	--	--
Solar power	Variable, lower yearly variance than hydro(?)	Heat (daily[36]/seasonal[37])	X	--

Figure 38 Power profile of Renewables

Approach 4 is the combination of different renewable energies. Because each of these sources has its own load profile has its own “system value” which is greater than the sum of the values of each individual energy source. A combination of these resources, with short-time capacity access financially honored, can bring more backup power to the market.

Each renewable energy has its own specific production profile. For some, such as biomass and hydro, storage technologies are well known and loss free; for others, additional new storage technologies are being scrutinized and are not related to the source of power.

[36] For solar thermal appliances

[37] For heat appliances

Approach 4
diversity of renewable supply

- combination of renewable sources
  - each source with specific load profile
  - smoothing out variability top some extent
- capacity availability should be financially honored
- "system value" of all renewables is bigger than cumulative value of individual sources.

Figure 39

Networking and interconnection of different energy supplies reduces cost and risks of wheather-related deliveries.

3.5. Approach 5 Interconnection

Approach 5
Interconnection

- Reduces variability or production
- Reduces storage demand and storage losses
- Higher security of delivery
- Opens up new resources
  - distant to load centers
  - Some with higher resource quality
- Opens access for new storage facilities
  - Norway, Sweden, Swiss, French hydro storage
  - Biomass CHP
- New interconnection technologies available
  - HVDC light (ABB)
  - Earth cabling

Figure 40

"Intermittency" some times is the wrong term. It suggests an uncontrollable power on-off-switch – like a light bulb in loose connection, blinking and annoying.

Many hostile arguments against solar and wind revolve around so-called full-load hours. It is the electricity production divided by the nominal value of the power capacity; in Germany, for example, you had a wind power capacity of 19'300 MW by June 2006 that delivers an expected 35.4

TWh electricity[38]; so full load production is 1834 hours a year at a capacity factor of 0,21.

Reality with Renewables is different though.

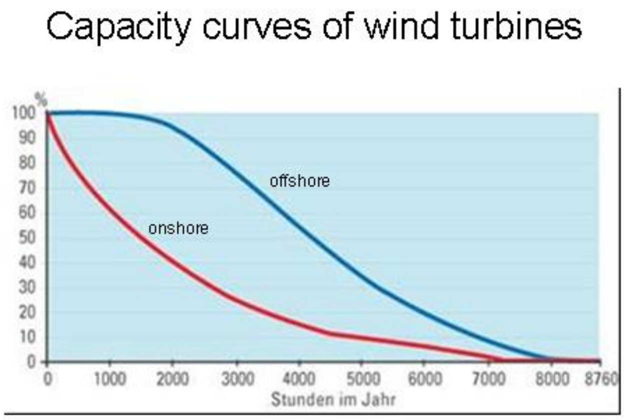

Figure 41 Wind Capacity curves onshore and offshore

Wind power systems run on partial load for most of the time, onshore maybe more than 60 percent and offshore maybe 80 percent of the year or more.

Wind power runs like a car that uses first to third gear mostly and for some hours a week runs in fourth gear, and some time is not running at all. The important characteristics of this car is not its speed, but its low investment, low operating and no fuel cost.

Wind and solar are "cars" which have an almost global availability for power and with benign ecological effects in comparison with non-renewable energy systems.

The modest capital cost of wind power enables one to attain *redundancy of supply* cheaper than with other sources, *interconnection and backup power provided*.

Say, three one-MW wind turbines placed in three dispersed locations produce electricity at a cost *below* that of an equivalent 1 MW new nuclear or coal-fueled base load generator.

So how can interconnection cope with variability of production, and what are the backup-capacities needed therefore?

[38] C. Ender: Wind Energy Use in Germany - Status 30.06.2006, Dewi-Magazin 29/2006 **http://www.dewi.de/dewi_neu/englisch/themen/magazin/29/06.pdf**

The German physicist Gregor Czisch has published very useful studies on intermittency and interconnection for a 100% renewable power system.[39] He made some important observations on interconnection:

1. Interconnection with High Voltage Direct Current (HVDC) lines over large distances does not imply prohibitive cost in financial terms or in terms of energy for a power system.
2. Interconnection makes it technically possible to deliver huge amounts of wind or solar power “just in time” without storage. Different weather zones can smooth out each other.
3. In this way, storage demand can be reduced and storage losses can be avoided. Renewable energy is more cost effective in this way.
4. With better interconnection new areas of renewable resources become available – some of them with higher productivities than former wind and solar plants localized in load centers.

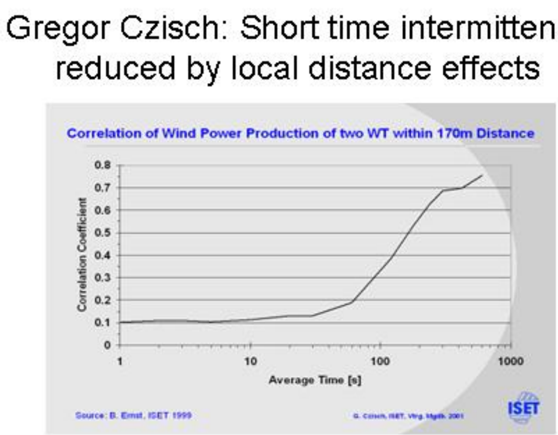

Figure 42 Czisch: Correlation 170 m Distance

In this figure you can see the correlation of the change of power from two wind turbines printed versus the averaging time. Fluctuations within short time intervals of some minutes are smoothened by the distance **within** one bigger wind park.

[39] http://www.iset.uni-kassel.de/abt/w3-w/sliden/magdeb030901/slide_65.html

To judge the value of wind and solar power, we should not look at one turbine or at one wind farm, but on a high number of wind facilities dispersed and interconnected over bigger areas.

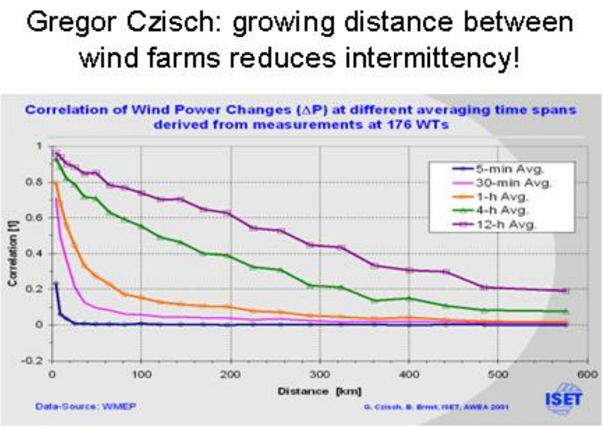

Figure 43 Czisch: More Wind Correlations

This graph shows how additional distance between wind farms reduces intermittency.

For example the 5 minute correlation falls to almost zero after a distance of 20 km.

While the 12 hour values reach a correlation coefficient of 0.2 at a distance of 500 km.

What means zero correlation in this context? It means that intermittent production starts to be totally independent each from the other. It means that there is a perfect "un-parallelism" between one turbine and the other.

From probability theory you know that the average of a big number of stochastic events turns out to be stable and predictable.

If you have for example 1000 GW of dispersed power with an average capacity factor of 0.25, the mean power output turns out to be 250 GW. But of course there still remain some regional or seasonal variations. At some days there will be more wind or solar power in the system than on others; the capacity factor does not exactly say how much power you have one day or the other, you can have some days with less and some with more.

Daily and monthly variability of wind power in Germany

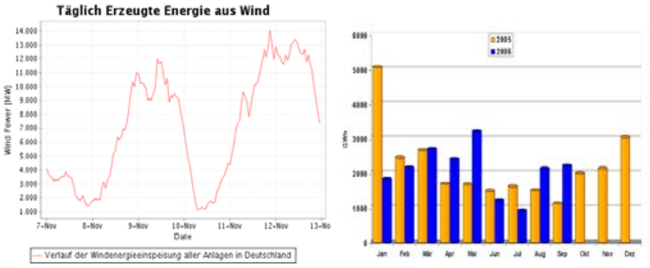

Figure 44 German Wind Power generation, daily and monthly

These daily variations can be considerable when you look at just one producer nation as Germany, shown in the picture.[40] On the right part of the slide you can see that monthly production values smooth out more equally.

cumulative wind power (Altenbenken and Oevenum /Germany)

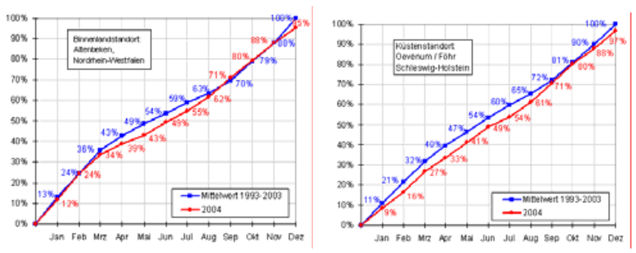

Figure 45 Examples of Wind Power yearly profiles

Over the year, differences tend to smooth out even more, even at one single place. So we can say that overall reliability of wind power is very good, but grid management and storage for back-up power are very important in terms of security of supply for the daily and monthly time frame, and the bigger the interconnected area, the less storage is needed.

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[40] Real time data on the German wind power production is available here: **http://reisi.iset.uni-kassel.de/pls/w3reisiwebdad/www_reisi_page_new.show_page?page_nr=353&lang=de**

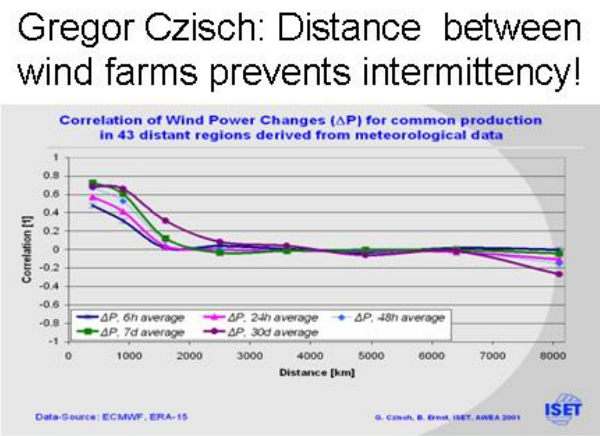


Figure 46 Czisch Wind Power Correlations, different regions

Gregor Czisch has analyzed wind power dispersed over very big distances in Europe and beyond – from Morocco to Russia for example. As we can see from the monthly mean, which is the dark violet line, the mean correlation drops down to almost zero at a distance of roughly 2000 km between two wind farms.

This means that when the wind-harnessing area spreads over such sizes, we will get mostly base load power, a secure band with predictable power from an endless resource. There is always wind some where, but we need to combine these places by a new European network!

3.6. Approach 6 backup power

Of course we will not achieve this from the first day. For smaller penetration of wind and solar, less backup is needed, though for smaller networks, more backup power is needed relative to load.

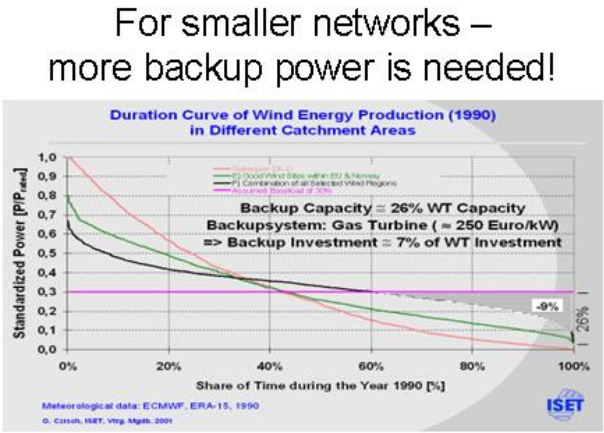


Figure 47 Czisch: Duration Curve and Back-up needs

The typical picture for interconnected areas looks like this:

- you have a base load demand of let's say 30% of rated wind power.
- you then have certain hours with excess power and some hours with excess demand.

Interestingly the simulations of Mr. Czisch say that even within small areas, most of the wind power is delivered just in time! To cover the demand of EU & Norway, Gregor Czisch calculated an installation of 660 GW of wind power over all European regions (and he ventures to integrate some neighboring regions too). This combined European network only needs some 9% back-up *energy* and 26% back-up *capacity* as a percentage of wind turbine capacity.

Figure 48: Wind power Generation and back-up necessities (source: Czisch)

	Wind power capacity GW	capacity factor	yearly hours 1000	expected power generation from wind	Back-up percentage necessary	neces-sary back-up
Generation	660	0.3	8.64	1710.72	9%	153 TWh
Capacity	660				26%	172 GW

These numbers may turn out much lower if we combine the system with other renewable sources such as solar, biomass, hydro and geothermal or when we add more hydro pump storage facilities within the system. But they give an impression of the necessary dimensions of a mainly wind driven European electricity system.

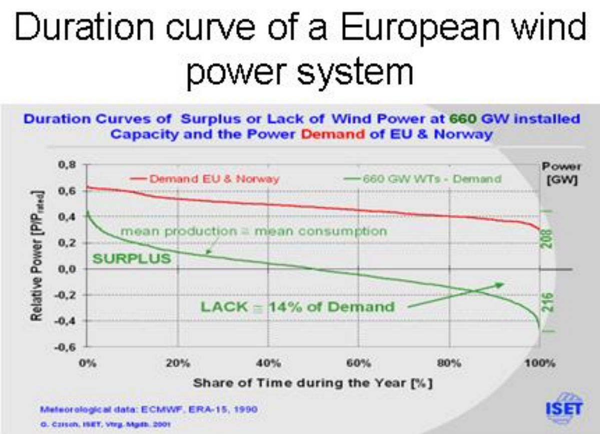


Figure 49 Duration curve European Power System

If we now consider producing the equivalent of the demand of EU and Norway from wind energy – without considering the insufficient interconnection between the neighbors – the demand for backup is higher. The duration curve shown in this figure represents a total rated power of 465 GW and a demand of 1940 TWh.

The maximum power demand is 295 GW, the minimum about 140 GW. The difference between wind power production and demand is shown in the green line. The maximum power surplus and maximum power shortage at some moments are each roughly 200 GW. The lack of energy amounts to 14% of the demand.

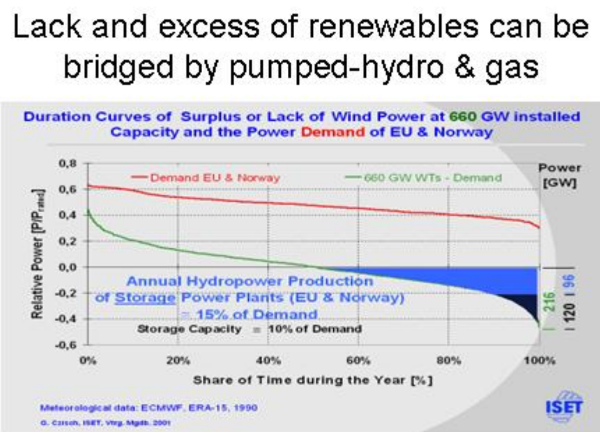
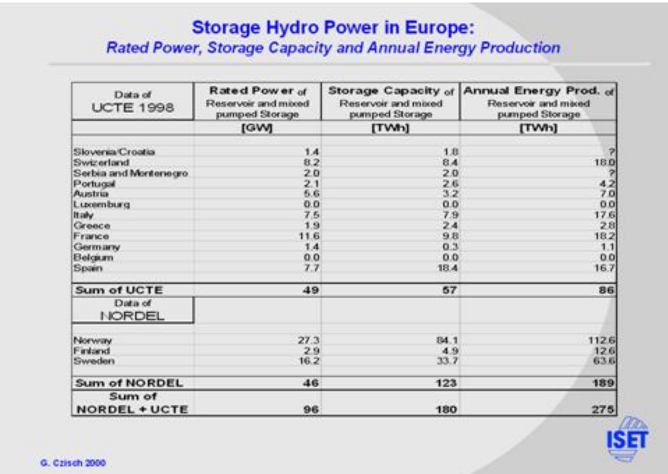


Figure 50 wind Power: Shortage and Excess Power

In Europe the lack of production could be bridged by pump storage and gas. A hydro storage system exists with relatively high rated power and some storage capacities, but these capacities are not linked to the emerging wind power production areas with adequate interconnection capacity. These hydro storage facilities mainly served for national power management.

If you look at this picture, you discover that within a merit order of storage systems you first and mostly use the hydro storage system with low variable costs. The gas power stations are spared for some rare occasions, due to their higher variable cost and capital cost rather modest.


Storage Hydro Power in Europe:
Rated Power, Storage Capacity and Annual Energy Production

Data of UCTE 1998	Rated Power of Reservoir and mixed pumped Storage [GW]	Storage Capacity of Reservoir and mixed pumped Storage [TWh]	Annual Energy Prod. of Reservoir and mixed pumped Storage [TWh]
Slovenia/Croatia	1.4	1.8	?
Swizerland	8.2	8.4	18.0
Serbia and Montenegro	2.0	2.0	?
Portugal	2.1	2.6	4.2
Austria	5.6	3.2	7.0
Luxemburg	0.0	0.0	0.0
Italy	7.5	7.9	17.6
Greece	1.9	2.4	2.8
France	11.6	9.8	18.2
Germany	1.4	0.3	1.1
Belgium	0.0	0.0	0.0
Spain	7.7	18.4	16.7
Sum of UCTE	**49**	**57**	**86**
Data of NORDEL			
Norway	27.3	84.1	112.6
Finland	2.9	4.9	12.6
Sweden	16.2	33.7	63.6
Sum of NORDEL	**46**	**123**	**189**
Sum of NORDEL + UCTE	**96**	**180**	**275**

Figure 51 European Hydro Storage systems

The annual storage of hydropower production within the European network is some 180 TWh or 15% of demand. So it is slightly higher than the lack of energy from the considered wind power system; hydro power today could well serve as a back-up for most of wind power added the next two decades or so, provided the interconnection is done.

But the 96 GW rated power of the storage hydropower plants is too small to compensate the lack of capacity at certain moments with low wind. The difference is some 120 GW.

There are many solutions to get the necessary backup power. One could be to enlarge the rated power at existing pump storage facilities, as it is done now in many places to provide higher peak load capacity.

Another way is to use thermal units, some of which could be fired by biomass.

There are more approaches of course, demonstrated in the next approach.

But as a main conclusion we must keep in mind that better interconnection is the priority way to go, because the losses are smaller with more just-in-time consumption and because interconnection can give new access to existing storage facilities.

state of the art: 1-3 GW capacity
many new projects – earth cables cheap

Figure 52 High Voltage Direct Current (HVDC) Examples

HVDC lines can interconnect different wheather zones.[41] The loss over 1000 km distance is lower than 4-5 percent; these investments are long-term and therefore very cheap in the long run. HVDC over long distances are cheaper than AC-overhead-lines, as was shown recently by one of the main producers in this field, ABB, which connected the Three-Gorges-power-plants[42] with the load centers at the

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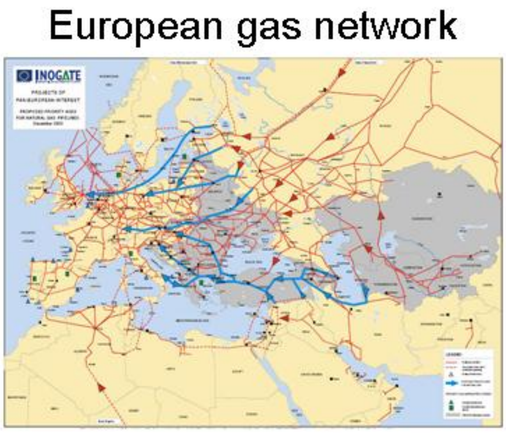
[41] See ABB: China HVDC Transmission **http://search.abb.com/library/ABBLibrary.asp?DocumentID=1JNL100100-972&LanguageCode=en&DocumentPartID=&Action=Launch**

[42] See: ABB/PEI: HVDC Transmission, SPECIAL PROJECT COLLECTION, May 2004

China cost.[43] ABB today declares that “Offshore grids can be built at competitive costs”.[44]

Remember just how big and how costly the European gas system is. Renewable electricity can play a more important role in the long term because it is an endless resource.



<u>Figure 53 European Gas network</u>

Looking at the existing gas network we can see that the construction of a European HVDC network from periphery production centers to central consumption places historically is not a new or exceptional task.

We must keep in mind here that wind power is or will be the most economic option: Strong indications from Germany, Denmark and Spain show that a higher penetration of wind power reduces spot market prices as was recently shown at the wind power integration conference in Brussels. [45]

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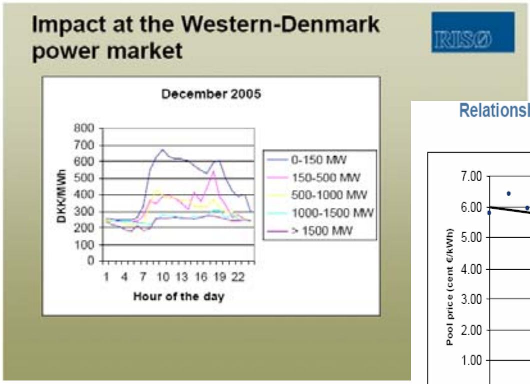
[43] Bo Nomark: Transmission Technologies to Support Integration of Wind Power, Large Scale Integration of Wind Energy, EWEA Policy conference, 7 - 8 November 2006, Brussels
http://www.ewea.org/fileadmin/ewea_documents/documents/events/2006_grid/BO_Nomark.pdf

[44] Nomark l.c. p. 18

[45] See Alberto Ceña: LARGE SCALE INTEGRATION OF WIND ENERGY
http://www.ewea.org/fileadmin/ewea_documents/documents/events/2006_grid/alberto_cena.pdf, Poul Erik Morthorst: Impacts of Wind Power Integration, Risø National Laboratory,
http://www.ewea.org/fileadmin/ewea_documents/documents/events/2006_grid/PoulErik_Morthorst.pdf
and Bode/HWWA, l.c.

Denmark & Spain: high wind penetration reduce spot prices
(source Morthorst/Risö Institute)



The Spanish Case

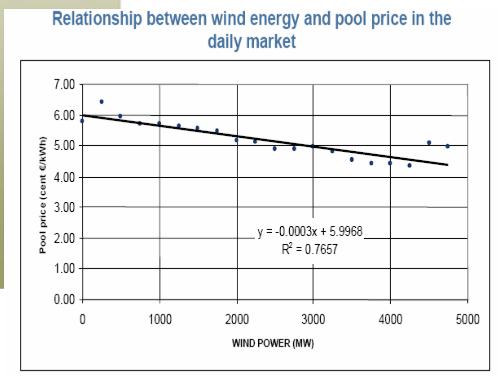


Figure 54 Wind Power penetration and Spot Prices

The reason for this is that additional wind power reduces power consumption from expensive facilities. Because wind power variable cost is near zero, additional wind feed in reduces the fuel costs from more expensive production units.

The Danish example:
cheaper electricity price due to wind
source: Morthorst 2006

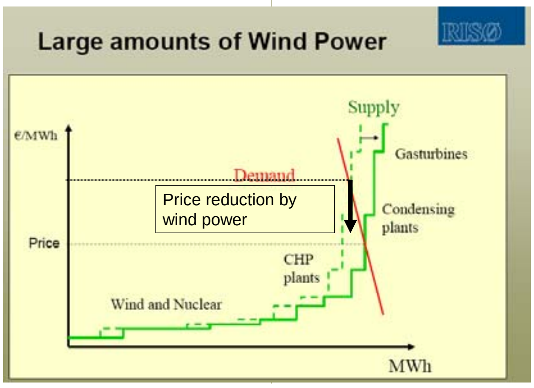


Figure 55 merit order: Danish Example

In this Figure we see the merit order of electricity capacity. When the wind blows, the supply line wanders from the dashed line to the strait line and the price falls.

Grid operators insist though that "*delivering the single electricity market and promoting renewable energy sources induce higher costs for Transmission System Operators. Building new interconnection lines not driven by demand, subsidizing the connection of renewable sources, internalizing balancing costs for intermittent generators, or restarting research and development programs abandoned since deregulation, are costs that will not be compensated by higher volumes of electricity delivered to the customers. In other words, these policies lead inevitably to higher transmission tariffs.*"[46]

But this additional cost for transmission is rewarded by lower pool prices. And a recent study by the International Energy Agency's renewable section[47] shows that integration cost of wind power into the grid can be summarized at 0.5-4 €/MWh. That is 0.05-0.4 €C./kWh and seems to confirm that the "reduction of pool prices is higher than increase of balancing costs", as was declared for the Spanish electricity market.[48]

3.7. Approach 7 more storage options

For the future there is a possibility of additional storage. Storage facilities have many benign impacts: they contribute to system and supply security, they reduce fear of lack of power and cost of consumer backup systems such as emergency generators and finally they can smooth out spot prices, selling in times of scarce delivery or peak load and buying at times of abundant supply and low consumption.

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[46] See Daniel Dobbeni, President European Transmission System Operators: Prospective of wind power in the national and European electricity supply **http://www.ewea.org/fileadmin/ewea_documents/documents/events/2006_grid/D.Dobbeni.pdf**

[47] Hannele Holttinen,Operating Agent, IEA WIND Task 25: Estimating the impacts of wind power on power systems; first results of IEA collaboration; **http://www.ewea.org/fileadmin/ewea_documents/documents/events/2006_grid/Hannele_Holttinen.pdf**

[48] See Cena 2006 l.c.

Efficiency of pumped-hydro storage ~80% better than many other storages

Table 3: Various storage technologies and typical technical performance

Storage technology	Typical round-trip efficiency (in %)	Typical capacity
Pumped-hydro station	~80	>100 MW - >1000 MW
Compressed air storage	~75	>50 MW - >100 MW
Flywheel	~90	>1 kW - >50 kW
Conventional batteries	~50 - ~90	>1kW - >10 MW
Flow battery	~70	~15MW
Hydrogen fuel cell	~40	>50 kW - >1 MW

Quelle: IEA: Variability of Wind Power and other Renewables, Paris 2005 S:27

Figure 56 IEA: Storage technologies

When we look at different power storage techniques we see that pump storage figures as one of the best solutions with an in-out-efficiency of some 80%. Hydro pump storage might be used in many more places in the world than now, even in places without high mountains or steady water flows, and in some places they may be driven by sea water.

Beside pump storage many new systems are emerging which might be competitive soon: Pumped air, batteries, heat storage and management (with electrical heat pumps), electric battery cars or hydrogen systems. For a diversified power management all these technologies need more research and optimization.

3.8. Approach 8 spread location of Renewables!

Continental interconnection opens the way for wind farming complementing each other, from the Mediterranean to the North Sea region for example, from Spain to Poland, from France to Russia, summer and winter, day and night propensity! If we take more technologies like existing hydro, geothermal, biomass or solar, more combinations can be managed within the same grid and there may be a trend for long term cost reductions.

3.9. Approach 9 production share agreements

What may be common one day is a term well known in the oil business: PSAs or production share agreements with cross-participation between solar, hydro, geothermal and wind in different regions. One must think of new transnational infrastructures mixes with different technologies, sending their power to the consumers in cost efficient, more smoothed manner than ever before.

3.10. Approach 10 Incentives for consumers

Then we should not forget demand side management.

Market incentives are necessary and can pave the way to more interconnections and storage through auctions of power and power transmission.

In a market system, it is necessary that abundance and scarcity of power can be felt by consumers too. Real time tariffs are one instrument; demand side management must be done and low or high tariffs should be made more visible for consumers. Factories must switch off in critical hours and should get cheaper electricity at times of abundant energy.

At least ten approaches to cope with variability of production and load

1. put intermittency in perspective 2. reallocation of cost burden 3. Non-renewable energies 4. diversity of renewable supply 5. Interconnection	6. backup power storage 7. New storage options 8. spread location of renewables! 9. production share agreements 10. Real time tariffs/Incentives for consumers

Figure 57

So there are at least ten different approaches to cope with variability of production and consumption.

4. Actual and future role of Swiss hydro storage in an open European electricity market

Hydro storage is a cheap and traditional method for matching power production and consumption in Switzerland.

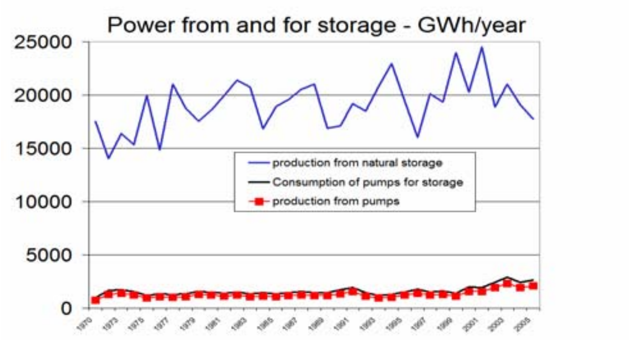
The Swiss experience with hydro storage power

- Expensive construction
  - High up front costs
  - Long planning
  - Long permit processes
- Cheap marginal cost
  - No fuel cost
  - Life expectancy of installation > 100 years
- Base load and peak load available
  - Special investments needed

Figure 58

Growing trade and the emergence of new market places in the European power system have an ever stronger influence in the Swiss power management.

Natural storage and pumped storage production in Switzerland



<u>Figure 59 Swiss hydro storage (blue) and pump storage production</u>

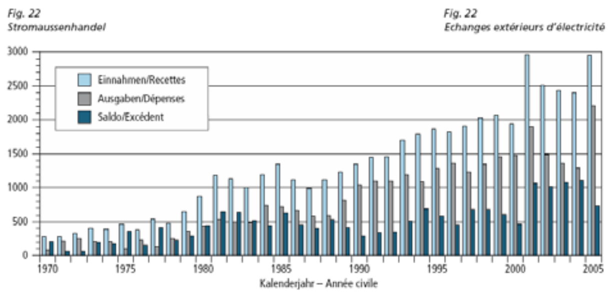
Switzerland has a lot of storage facilities and a thorough assessment of the potentials for a solar and wind power management with adequate finance, based on recent price trends, is not done yet.

Pump storage played a minor role because there is so much seasonal storage.

But one can see here that the amount of pumped storage is growing recently when natural storage is not growing much any more. The motor behind this is additional profits.

Revenue, Expenses and Profits of Swiss external electricity Trade

source BFE: Swiss Electricity Statistics 2005 (Million Swiss Francs)



<u>Figure 60 Revenue from Swiss Electricity External Trade</u>

higher electricity prices and volatility drive the expansion of Swiss hydro facilities as can be seen in the Figure. The share of short-term agreements (up to two years) in electricity trade has grown from 46% to 80 % since 1999 reflecting a trend to of more market oriented delivery of power.[49]

The question is: How much back-up power and capacity services can the Swiss hydro system contribute in the future for a more renewable European power system?

Various services may be considered:

- Backup capacity within minutes up to one hour
- Backup capacity from one hour to six hours
- Backup capacity for many days in case of a weather related wind calm
- Ability to store wind power for the whole weekend or more.

[49] Schweizerische Elektrizitätsstatistik 2005 p.37 Table 31

It is not possible here to give a concluding answer for future developments. We only can give an *idea* what the extent today is and what it might become in the future.

4.1. Merit Order Of Storage

We must remember that before pumping and storing wind or solar energy, the first thing to do will be to drop off fossil power generators from expensive peak power plants with high variable cost, such as natural gas fired peak plants.

When these capacities are reduced and in case that there still is excess power in the system, leading to lower prices, the next thing to will be to follow a merit order of storage solutions. Swiss hydro power generators have the choice to do two things:

- They can stop running hydro power from seasonal storages
- They then can start pumping water upwards to increase power storage.

Some organizational and facility specific conditions must be considered in this regard:

- There must be free water storage capacity to pump upward
- Today, many storage facilities just follow the load curves of their owners, i.e. cities or cantons. Some of them do not trade power and never did, or they trade power just in the extent of excess storage capacities.
- Taking advantage of the Swiss storage system implies that you do not consume your own stored assets, but accept power from the European market in periods of *cheap* energy.
- On the other hand, in periods of high prices you must be able to deliver your own customers mainly in the cities of the midlands and, additionally, you must have enough capacities (power, stored water and interconnection) to deliver clients abroad! Interconnection though is a scarce good meanwhile, and transnational auctions for access make it less interesting to deliver abroad!
- To use stored power for trade, storage facilities must be able to curtail their power at times with low prices. Not all storage facilities

have adequate capacity to concentrate their energy for better paid periods only; in that situation they sometimes have to drain their water just to get rid of it.

Without these essential infrastructure it will not be possible to store water in windy times or to sell to the market in times of wind calm.

4.2. Environmental Pro and Cons

There are more restrictions to consider. To be ecologically benign, additional conditions must be fulfilled[50]:

- Water balance restrictions: some facilities may turn on generation only slowly to prevent a "tsunami or drought impact" for water wild life.
- Residual water flows must fulfill environmental standards.
- The amount of water to be used depends to an extent on rainfall and snow melt. Without precipitation, no electricity production is possible.

Ecological conditions for pumped storage

• ecological condition	• Swiss Power Industry stand
• Clean energy: Power Intake must come from renewables	• new renewables not accepted, nuclear agenda continued
• dry river beds must be restored	• drains profits, strong opposition
• no tsunamis for fish and water ecology, management basins needed	• basins accepted for pump storage, water protection contested
• earth cables instead of new power lines over landscapes	• earth cables contested, one HVDC from Graubünden to Milano planned though
• protection of nature parcs and unique sites	• expansion on protected areas

Figure 61 Environmental Road Map

To be "clean energy" the intake for excess load must com from solar or wind sources; up to now they came from coal and nuclear, and still Swiss power companies want to ex-

[50] See the electricity program „Toward 100% renewable energy" by the Social Democratic Party of Switzerland(Sicher und effizient umsteigen, Unterwegs zur Vollversorgung mit erneuerbaren Energien, Perspektivpapier der SP Schweiz

pand its shares denying the value of wind and solar technologies.

Then we have to re-vitalize the dead rivers downstream the big storage facilities and we have to prevent "tsunamis" when stored water is released. This can be managed by water balance basins which can be used for pumping as well. By creating additional basins underneath of storage facilities, hydro pump storage and water protection can be combined, but the necessary investments are costly and permission procedures take much time.

4.3. An Attractive Business

In the overall picture we today can identify the fact that it is more interesting to do day-to-day or weekend-to-workday-business due to

- Better price differences than ever before[51]
- More frequent business occasion and better use of capital therefore
- Low variable cost and high efficiency compared with other peak generation or storage facilities. [52]

Seasonal storage in the future might be a safety cushion for the Swiss consumers, maybe essential in case that the Swiss power investors will engage in offshore wind power where sea shore lines are some 1000 km distant form the Swiss load centers. But the essential trade will take day over day and week over week.

Swiss power capacities and excess power capacities MW Source: swiss electricity statistics, mean values 2004 and 2005						
month	1	2	3	4	5	6
hydro run of river	1275	1219	1138	1600	2455	2896
hydro storage capacity (95%)	8983	8983	8983	8983	8983	8983
nuclear and conventional	4075	4075	4075	4075	4075	4075
total dispatchable	14332	14276	14195	14657	15512	15953
Swiss consumption (without pumping)	9478	9523	8836	8715	8491	8659
available excess power	**4855**	**4753**	**5359**	**5942**	**7021**	**7295**

[51] Former studies on the subject calculated with symmetric prices for buying and selling power. Meanwhile the time of permanent overcapacities seems to be over. Volatility on the market is much higher than in the 90es, and the wind power share is growing faster than ever before. See Bundesamt für Energie: Windenergie und schweizerischer Wasserkraftpark, Februar 2004

[52]

Month	7	8	9	10	11	12
hydro run of river	2879	2481	2004	1407	1071	990
hydro storage capacity (95%)	8983	8983	8983	8983	8983	8983
nuclear and conventional	4075	4075	4075	4075	4075	4075
total dispatchable	15936	15538	15061	14464	14128	14047
Swiss consumption (without pumping)	7959	8348	8620	8864	9249	9720
available excess power	**7977**	**7191**	**6442**	**5600**	**4880**	**4328**

Figure 62 monthly power capacities and excess power capacities MW in Switzerland

So what is and would could be the extent of the Swiss backup capacity?

As can be seen from the figure, the “normal” excess capacity without pump storage is between 4,3 GW (December) and 8,0 GW in July with a mean of 6.0 GW. The Swiss power profile fits well with wind the power profile where summer demand for peak power is highest.

With additional wind power in the European grid, there will be more and more weekends and night with cheap and abundant base load power on the market.

Due to their seasonal character, in general the Swiss hydro storages are big enough to keep their water over several stormy nights or at weekends, to sell it at peak times during workdays. For day-to-day smoothing of wind and solar power we will not need to tap the full potential of these water storages.

So if we assume that seasonal storage capacities will be used for peak delivery only, we can say that these facilities can contribute some 7.47 GW capacity which is 4,3 % of the supposed back-up necessity of some 170 GW. The medium power production of these facilities of 18’832 GWh would be 12 %.

	GWh medium production	GW capacity
sesonal storage plants	17’258	5.9
pump storage plants	1’574	1.57
Total dispatch able power	18’832	7.47

Figure 63: available capacity and medium production 2004/2005

We must ask though if it would be possible to grow the low capacity factor of existing pump storage facilities. If we assume that pumps work with a capacity factor of 0.33, backup generation would rise from 1.57 TWh to 4.0 TWh and the Swiss storages could cover 13.8 percent of the back-up power needed.

4.4. Capacity extensions and more pump storage

In many cases the seasonal water storages are so big that they could produce more power over a shorter time frame, and with pumping, they could use the same water at a much higher frequency. In this way Switzerland could exchange higher amounts of seasonal storage or pumped electricity for periods with high consumption or low wind.

A number of new projects are being planned in Switzerland to raise pumped storage capacity. They all rather modify existing facilities than creating new ones.

Many of these projects add more pipes and generators between two existing storage lakes to create more power and often they are invisible constructions under the earth.

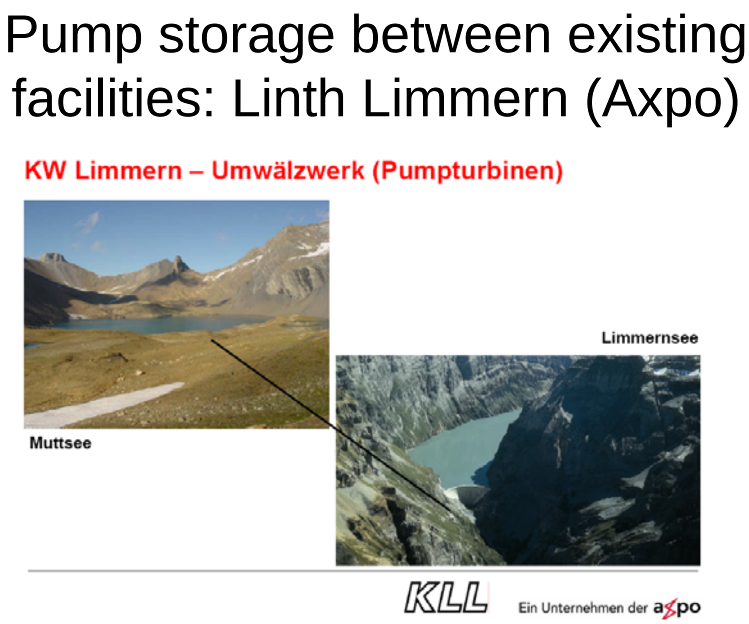


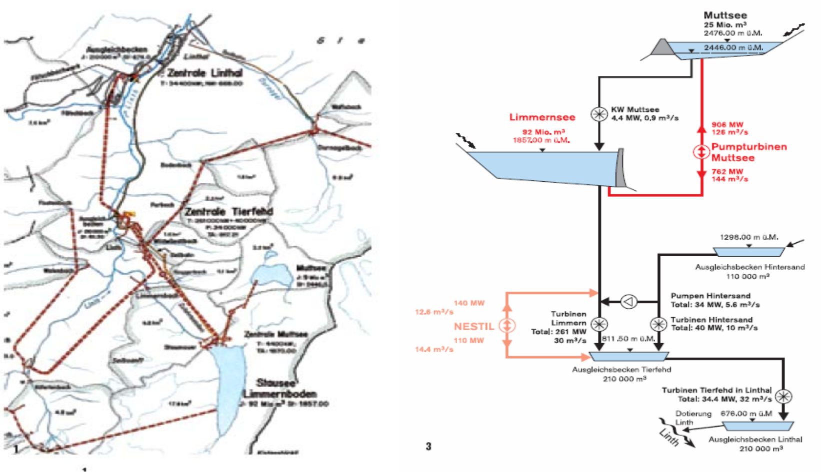
Figure 63 Axpo Project

The Axpo project of Linth-Limmern with a combined capacity addition of some 1050 MW is one of these new constructions that might start soon.

Figure 64 Axpo project, situation map

There will be enough capacity to pump more than 1 GW for a whole weekend – Friday night until Monday morning and to sell it over the rest of the week during peak times.

Complex projects with new basins below and higher pump and turbine power



Source Axpo/ Linth-Limmern

<u>Figure 65 Axpo Project: Details</u>

It is a complex project and the cost estimate is around 1 Million € for 1 MW of additional power.

The important (and difficult) part of these projects are not the storage facilities up on the mountain – they mostly exist already in a big way – but rather the balance basins below that keep the higher amount of water after passing the turbine!

A number of similar new pump facilities and capacity additions for seasonal storages are in planning stage, with a combined addition of 6,3 GW!

At least 6 GW of additional hydro-stored power possible

New project	new pump storage capacities	additional peak load of existing storage facilities	cost MCHF	cost MCHF/ MW	time frame
Cleuson Dixence		1200	>1000		2010
Vieux Emossoon VS	600		n.a.		
Linth Limmern GL	1200		1000	0.83	2015
Nestil GL	140		n.a.		
Oberhasli KWO plus E	1050		1000	0.95	
Sambucco TI	960		1000	1.04	
Val d'Ambr TI	70		n.a.		
Verzasca II TI	300		n.a.		
Nant de Dranse/Vieux	600		n.a.		2015
Lago Bianco GR		150	400	2.67	2016-18
Total	4920	1350			

Figure 66 Capacity Extensions In Switzerland

Power capacity medium case	GW	daily hours of pumping	TWh	power intake	losses
sesonal storage	6	-	17		
existing pump storage	2	8	5	6	1
additional pump capacity	6	8	18	23	5
Total	14		40	29	

Figure 67 Swiss Excess Capacity Medium Case

Power capacity high case					
Swiss excess capacity	GW	daily hours of pumping	TWh	power intake	losses
sesonal storage	6	-	17		
existing pump storage	2	12	7	9	2
additional pump capacity	6	12	28	34	7
Total	14		52	43	9

Figure 68 Swiss Excess Capacity High Case

Realizing the proposed projects, Switzerland could prepare some 14 GW of back-up power for to the European grid and – in the extreme case of 12 hours of pumping a day could deliver some 50 TWh of energy at peak time. This would fulfill some 8% of maximum back-up capacity demand of a almost purely wind driven European system as calculated by Gregor Czisch and some 32 % of backup production.

This means that Switzerland could manage all of the German and Danish wind farms for most time of the year, but that at some rather short moments additional *capacity* – from renewable or fossil fuels such as natural gas – must be added to maintain the system.

With some 50 TWh disposable, Switzerland would be the backbone of the European electricity trade.

In 2005 the average spread of buyer's and sellers prices was 0.0255 CHF/kWh and electricity trade contributed around 1 billion CHF/year since 2001 on average.

Swiss Electricity trade: prices	CHF/kWh
Selling	0.0726
Buying	0.0471
Saldo	0.0255

Figure 69 electricity trade margins in Switzerland (2005)

To make the huge pump capacity extensions profitable, the spread of selling and buying prices would have to rise. For the moment it is more attractive to sell seasonal storage power in the right moment without pump losses than to pump and sell. Large, integrated electricity companies are favored to do this job. For this reason most of the Swiss power companies sought cross participation with European power giants such as Electricité de France or Eon.

Axpo: notoriously nuclear oriented

<u>Figure 70 Axpo planning</u>

Slide taken from fact sheet presentation by Axpo Power Company: "*Axpo plans base load from 2020 parallel: … renovation and optimization of hydro run of river… power imports from gas, coal and nuclear from its own or from third party power plants … combined gas power plants and in a later step production from a new Swiss nuclear plant*".

New renewable energy non existent or just in a micro-show-case-you-see-it-does-not-work mode.

We should pay urgent attention to the fact that all the big Swiss companies have a predominantly nuclear or non-renewable script. They do not trust wind or solar technologies and they finance massive pro-nuclear campaigns.

So we should not be naive. NGOs must insist that power for hydro pump storages must be derived from Renewables and that nuclear power must be phased out, this should be a package deal.

Otherwise all the additional hydro capacities will only serve to accommodate more nuclear plants, and environmental impacts of additional storage would be detrimental for eco-systems.