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Energy Economics, Winter Semester 2023-4
Lecture 8: Support for Renewables

Prof. Tom Brown, Philipp Glaum
Department of Digital Transformation in Energy Systems, Institute of Energy Technology, TU Berlin

Table of Contents

Why renewables require support

Questions we want to answer

- Why do renewables require support?
- Why can't solar and wind survive from electricity market revenue alone?
- What types of support are there?
- What are the pros and cons of direct payments, premiums, taxes and quotas?
- What should support look like once wind and solar are mature?
- What is the most efficient way of reaching greenhouse gas reduction targets?

Motives for renewable support

- reducing carbon dioxide emissions
- reducing air pollution (particulate matter, NOx, SO_2 from fossil fuel combustion)
- reducing dependence on finite resources (fossil fuels, uranium)
- creating energy system with decentralised structure and ownership (reduces market power)
- reducing cost through knowledge spillovers (leading to lower overall cost energy system)
- developing an export industry by early specialisation
- energy security: limiting dependence on fossil fuels imports
- ancilliary benefit: generating employment

Why is support necessary?

Why not just rely on **market revenues**?

Or on **carbon pricing** to make low-carbon generation attractive?

The reasons for support are varied, depend on technology, maturity and the penetration of the technology in the market.

- The technology is at the beginning of its learning curve and is **expensive** but there is an **expectation of cost decline** that will make it competitive in the future
- The technology is competitive but not being built because of **price risk**
- The technology penetration is so high that in the absence of other policy (e.g. carbon pricing) there is **cannibalization of market value**

Wind and solar cost developments

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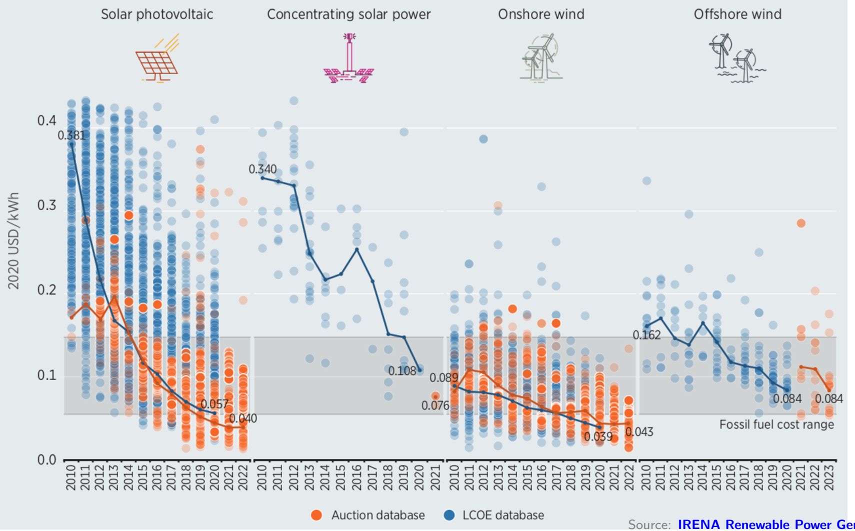
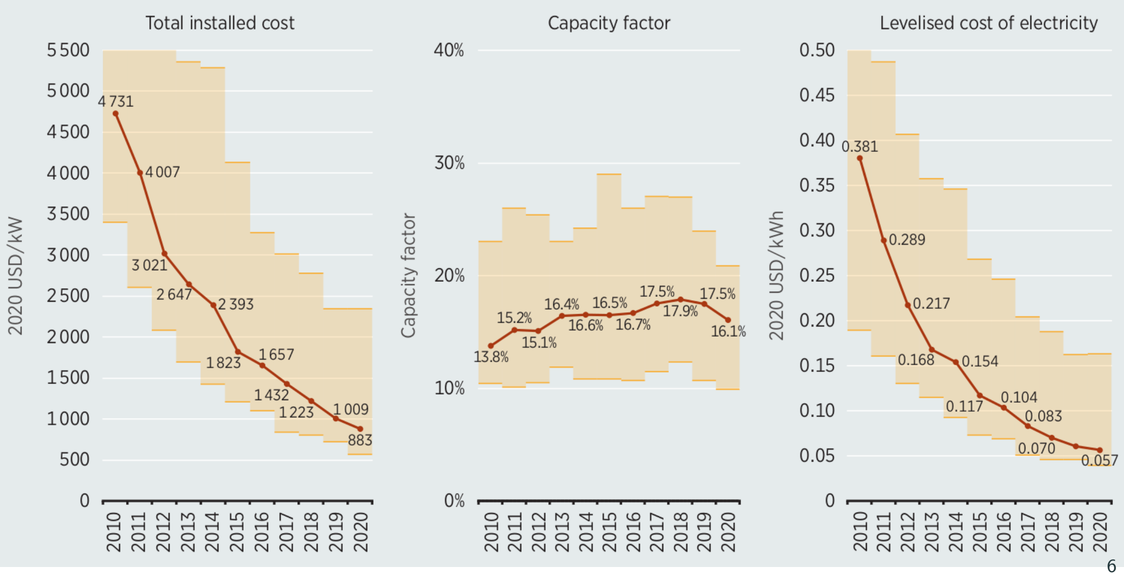
Project and global weighted-average LCOE and PPA/auction prices for 2010-2023:



Source: IRENA Renewable Power Generation Costs in 2020

Global weighted costs for solar PV

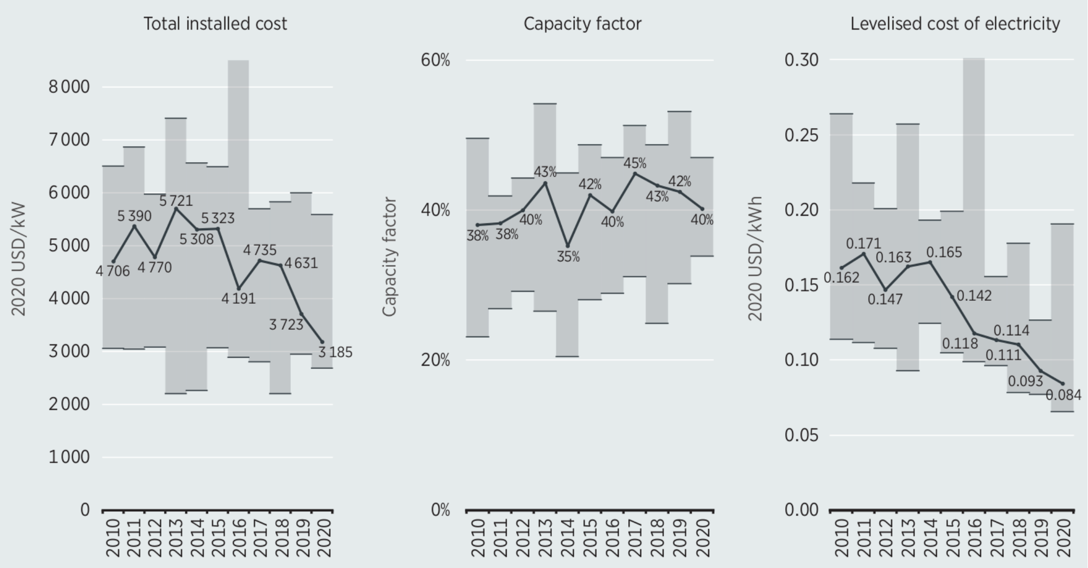


Source: **IRENA Renewable Power Generation Costs in 2020**

Global weighted costs for onshore wind

Source: **IRENA Renewable Power Generation Costs in 2020**

Global weighted costs for offshore wind



Source: **IRENA Renewable Power Generation Costs in 2020**

Market value

VRE have the property that they cannibalise their own market, by pushing down prices when lots of other VRE are producing through the **merit order effect**.

They reduce their own revenue by producing in a correlated way.

To quantify this effect, we can define the **market value** of a technology by the average market price it receives when it produces, i.e. for technology s and production at time t of $g_{s,t}$ MWh when the market price is p_t €/MWh:

$$MV_s = \frac{\sum_t p_t g_{s,t}}{\sum_t g_{s,t}}$$

We can compare this to the average market price, defined either as the simple average $\frac{1}{T}\sum_t p_t$ or the demand-weighted average $\frac{\sum_t p_t d_t}{\sum_t d_t}$.

Historic market values in Germany

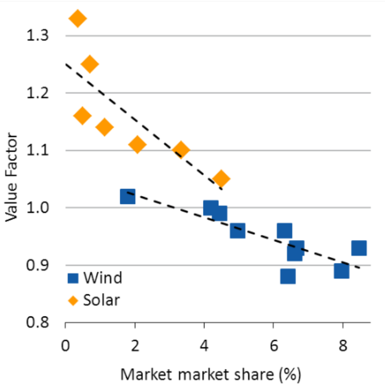


Figure 6. Historical wind and solar value factors in Germany (as reported numerically in Table 3).

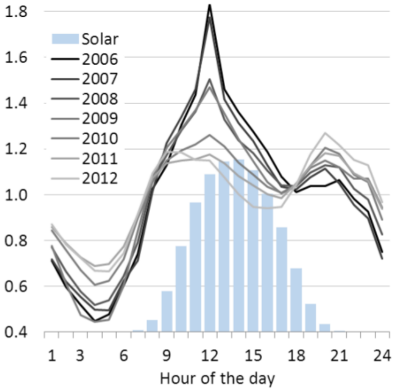
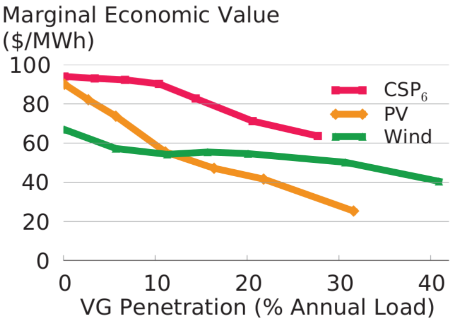


Figure 7. The daily price structure in Germany during summers from 2006 – 2012. The bars display the distribution of solar generation over the day.

Source: Lion Hirth, 2013

Market value at higher shares

At low shares of VRE the market value may be higher than the average market price (because for example, PV produces a midday when prices are higher than average), but as VRE share increases the market value goes down.

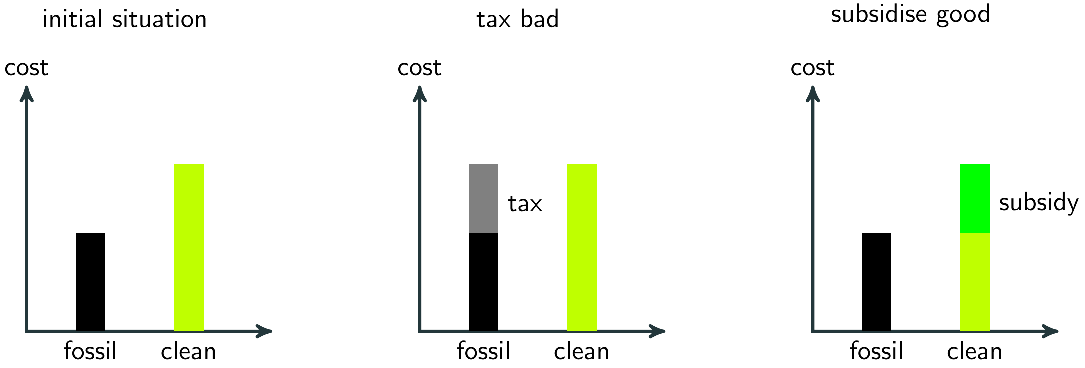


The effect is particularly severe for PV, since the production is highly correlated; for wind smoothing prevents a steeper drop off. The bigger the catchment area, the longer wind preserves its market value.

Source: Mills & Wiser, 2014

Taxing bad versus subsidising good

In general if you have two competing technologies and you want to encourage the more expensive one, you can either **tax** the disfavoured technology until the favoured technology is preferred, or you can **subsidise** the favoured technology.



Taxing bad versus subsidising good example: electric vehicles

To encourage electric vehicles (EV) over internal combustion engine vehicles (ICEV), we do both in Germany:

- **energy tax** and **CO_2 tax** on diesel and petrol
- **vehicle sales tax** (Pkw-Steuer) only applies to ICEV
- **subsidy** (Elektro-Auto-Kaufprämie) for electric vehicles of up to €9000 (sinks to €6750 in 2023, zero in 2024)
- **state regulatory and financial support** for charging stations

Price versus volume

Alternative to taxes and subsidies: set target for **volume** instead of **price**, e.g. fixed **quotas** (e.g. for biofuels in transport fuels, renewable power in generation, maximum emission standards) or regulation banning technologies (coal exit, ban on gas boilers).

Example 1: to limit carbon dioxide emissions: set **volume limit** then trade certificates for this emissions volume (like EU Emissions Trading System (ETS)) OR set **carbon price** determined administratively.

Example 2: to raise share of renewables: set **renewable share target** with tradeable certificates for generation (like Renewable Portfolio Standard (RPS) in some US states) OR set **feed-in tariff** determined administratively.

Types of support schemes for renewables

- **Public financing** - public investments, loans, grants
- **Corporate financing** - Power Purchase Agreements (PPAs)
- **Fiscal incentives** - subsidies and tax reductions for RES or taxes on carbon
- **Quotas for consumers** - required shares for renewables or clean energy

Fossil fuel subsidies should also be removed

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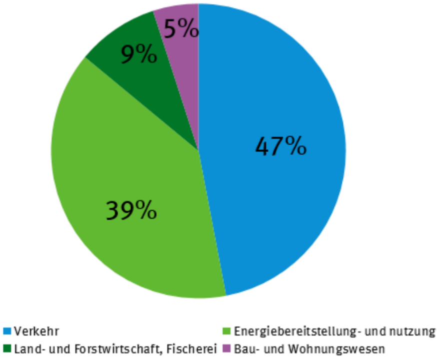
The Federal Environmental Agency (UBA) estimates that in 2018 in Germany there were environment-damaging subsidies of €65.4 billion, of which €60.6 billion damage the climate.

Major factors include EEG exceptions, lower tax on diesel relative to petrol, energy-tax-free kerosene for aviation, VAT-free international flights, commuter tax allowance, subsidies for coal, lower VAT for animal products, free distribution of ETS CO_2 certifications.

NB: This does NOT include indirect subsidy of not taxing fossil fuel externalities for climate and air pollution.

Abbildung 17: Aufteilung des Subventionsvolumens nach Sektoren



Source: UBA, 2021

Policies

Worldwide policies

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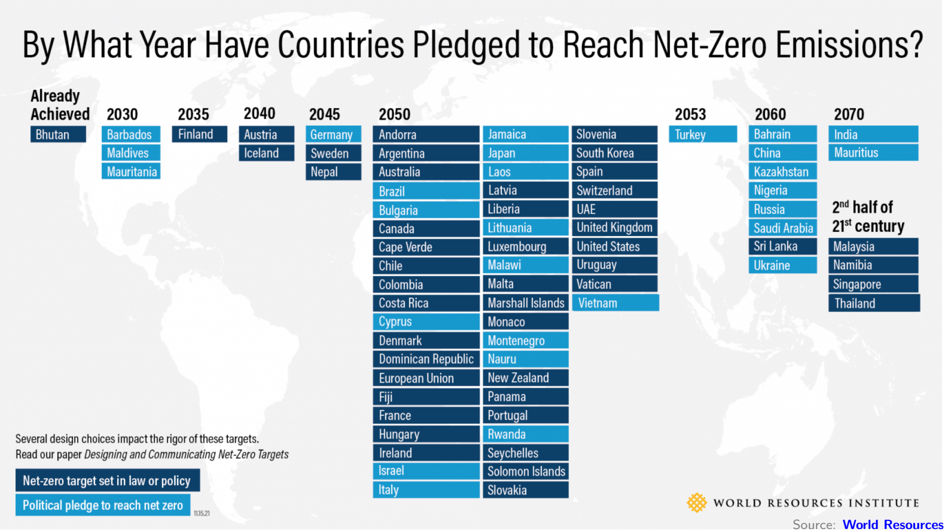
As of mid-Nov 2021 (after COP26 in Glasgow) 74 nations have net-zero emissions targets.



Source: World Resources Institute, 2021

European Union's climate and energy targets

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2030 energy and climate framework

Key targets for 2030 in 'Fit For 55' programme (RES regulated in Renewable Energy Directive (RED) III from 2023):

- At least 55% cut in greenhouse gas emissions (from 1990 levels; NB: not just CO_2, also other five Kyoto GHG)
- RED III: At least 42.5% share of renewables in final energy consumption (aiming for 45%)
- RED III: 42% of hydrogen should be renewable; 5.5% of transport fuels to be advanced biofuels or renewable fuels of non-biological origin (RFNBO); minimum 1% RFNBO
- Revised Energy Efficiency Directive: reduce final energy consumption by 11.7% compared to projections made in 2020

European Green Deal

- carbon-neutral economy by 2050 (i.e. net-zero greenhouse gas emissions)

Source: European Commission, 2023

REPowerEU: Response to Russian invasion in 2022

In March 2022 the European Commission proposed the REPowerEU plan to reduce dependence on Russian fossil fuels:

- Raise 2030 renewables target from 40% to 45% (weakened to 42.5% subsequently)
- Increased ambition on energy efficiency (to reduce gas demand by 15% this winter)
- Faster permitting of renewables
- Renewable hydrogen target in 2030 raised to 10 million tonnes per year (Mt/a) domestic, 10 Mt/a imported from outside EU
- Joint LNG purchases; double biomethane by 2030
- Targets for industry decarbonisation and raw material access

NB: Must be approved by European Council and Parliament.

Source: **REPowerEU, 2030**

Germany Klimaschutzgesetz (2019, updated 2021 and 2023)

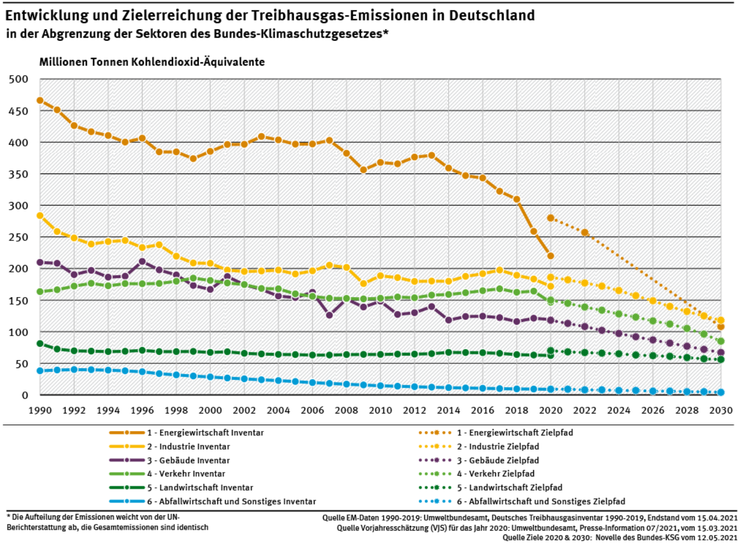
In 2021 the Germany Climate Protection Law (Klimaschutzgesetz) was updated after the Federal Consistitution Court (Bundesverfassungsgericht) ruled that the original 2019 targets would infringe on the rights of future generations.

New targets:

- Reduction of greenhouse gas (GHG) emissions in 2030 by 65% versus 1990 levels
- In 2040 by 88%
- Climate neutrality (zero net GHG emissions) by 2045
- Sector-specific targets for 2030, including for land use and forestry
- Expertenrat für Klimafragen monitors progress (modelled on Committee for Climate Change in UK); Sofortprogramm for ministries if targets not met
- 2023 Novelle: sector-specific targets abolished, replace with overall target

Source: **UBA, 2022**

Germany Klimaschutzgesetz (2019, updated 2021)



Source: UBA, 2022

German Renewables Act (2021)

EEG 2021 had targets:

- At least 65% share of renewable energy in gross electricity demand in 2030
- 100% CO_2-neutral electricity generation and consumption by 2050
- Continuous, cost-efficient and grid-adjusted RES expansion.

New targets in 2021-3 from the Traffic Light Coalition

The coalition raised the ambition of previous targets; renewables regulated in EEG 2023.

- gross electricity consumption assumed to rise to 750 TWh/a in 2030
- 65% → 80% renewable electricity target by 2030 (600 TWh/a RES)
- 100 GW → 215 GW solar PV target by 2030
- 71 GW → 115 GW onshore wind, 20 GW → 30 GW offshore wind target by 2030
- 50% climate-neutral heating
- coal exit ideally by 2030
- need hydrogen-ready gas turbines
- 6 million heat pumps, 15 million electric cars by 2030
- 10 GW of electrolysers by 2030
- abolished EEG-Umlage on 01.07.2022

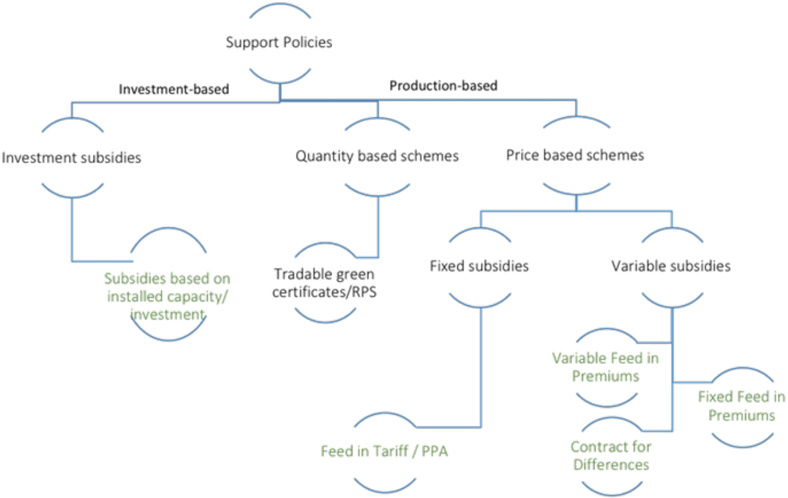
Source: **DIW Ampel-Monitor Energiewende**, 2022

Are the targets being met?

Checkout **DIW Ampel-Monitor Energiewende**.

Support mechanisms

Renewable Electricity Support Schemes in Europe



Note: Support levels in these schemes can be set both using auctions or administratively

Source: Open Electricity Economics

EU Clean Energy Package (2018): binding target of 32% for renewable energy sources in EU's energy mix by 2030.

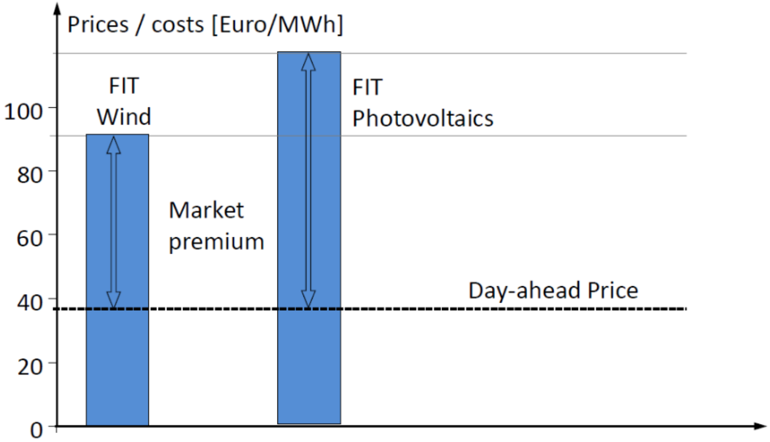
Price control	Obligation of grid operators (or ISO) to purchase all offered renewable electricity at legally defined (and technology specific) fixed feed-in payments	Dominant model but challenged by the EU Commission
Price control	Legally defined and technology specific market premium (on top of the market price) granted to renewable generators that have sold the electricity	Similar to Contract for Differences
Volume control	Obligation of retailers to hold a minimum number of Renewable Electricity Certificates (RECs) issued by registered renewable generators	
Volume control	Renewable portfolio standard (retailers must physically purchase a minimum share of renewable electricity)	Do retailers have the capacity to comply?
Volume control	Renewable investment tenders (government defines the renewable capacity additions and selects the investors that ask for the lowest market premium)	Model preferred by the EU Commission

RES support mechanisms: Administered fees (all-inclusive or premium)

- The government fixes the price for each MWh produced or injected into the grid from RES.
- Normally, the fee depends on renewable source and size of power plant.
- **Feed-in tariff (FIT)** provides fixed amount of money per produced MWh.
- A **market premium** pays the difference between the market price and a strike price, giving incentives for selling RES output directly on the wholesale market.
- If the premium or tariff is coherent with the production cost, the government's RES output target can be met; otherwise it would be not reached or exceeded.
- The charges linked to the support system are paid by final electricity customers.

Feed-In Tariff versus Market Premium

Market premium covers difference between average monthly **market value** of technology and pre-determined strike price, so that total payment is the same as the FIT for average generator. Direct marketing provides an incentive to produce more during times of high prices.



Market Premium Calculation

To calculate the **market premium** the TSOs in German are obliged to calculate for each month what the **market value** was for a reference PV or wind turbine. The market value is the price p_t in each hour t averaged over each generated MWh g_t

$$MV = \frac{\sum_{t \in \text{month}} p_t g_t}{\sum_{t \in \text{month}} g_t}$$

The market premium paid to the generator for each MWh is the **strike price** (fixed when generator approved) minus the market value, assuming market value $<$ strike price.

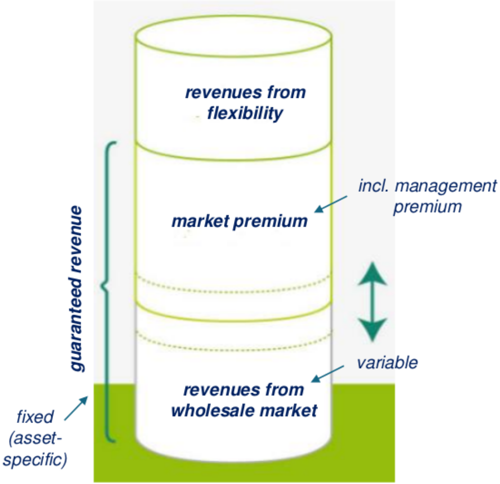
If the market value is **above** the strike price, there is no payment (strike price is a **floor price**).

Since the market value is based on a reference generator, the generator has an incentive to maximise its own market value to maximise its actual market revenue (e.g. east-west orientation for PV panel to capture morning/evening prices, or a low-wind-speed turbine).

Transparency website with monthly market values

Feed-In Tariff versus market premium

The market premium includes a fee for management costs.

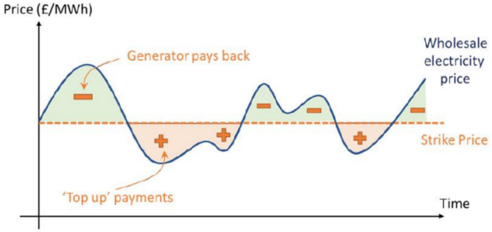


Source: Next Kraftwerke

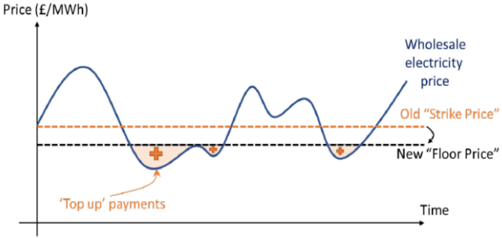
Market premium versus contract for difference

With a **contract for difference** (CfD), left picture, as used in the UK for nuclear and offshore wind, the state pays the generator when the market price is below the **strike price**, and the generator pays back the state when the market price is higher than the strike price. Good for consumers when prices are high!

The German **market premium**, like the right picture but based on a monthly average, only provides a **floor price** - the generator does not pay back when the market price exceeds the strike price, which leads to a lower strike price. The generator is thus incentivised to feed in power when prices are high.



Current CfD Mechanism



Floor-Price CfD Mechanism

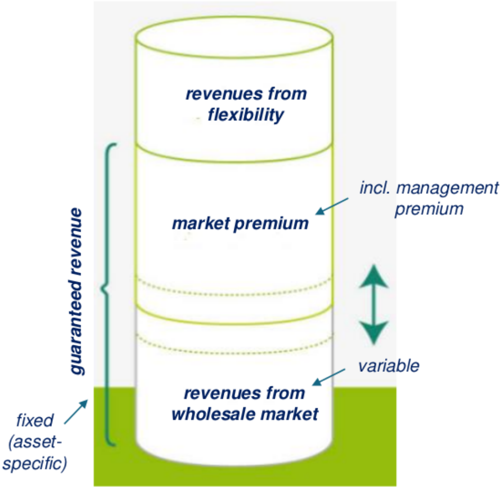
Auctions for market premium reference value

EEG 2017:

- Predetermined auctioned capacity for RES new build
- Prequalified projects bidding their reference value (guaranteed revenue)
- Installation-specific reference value

Auction requirement for

- Offshore wind
- Onshore wind and solar PV from 750 kW
- Biomass from 150 kW



Source: Next Kraftwerke

Market integration objectives of RES

Market integration objectives	Dimensions of achievement of objectives	Contributions to overarching objectives
Demand-oriented generation of RES electricity and increased flexibility of RES plants	Prevention of surplus supply situations via voluntary curtailment in times of negative electricity prices	Contribution of RES to security of supply is increased;
	Shift of feed-in to times when demand is strong and prices are high:	Costs of RES promotion are reduced through an increase in RES market value;
	• Intermittent RES: Maintenance planning, installation design oriented towards market value and system requirements	Cost reductions in the overall system (e.g. lower balancing energy prices and system integration costs)
	• Dispatchable RES: targeted load shifting	
	Increased remote controllability of RES installations	
	Participation of RES installations in the balancing energy market	
Efficient marketing of RES electricity	Reduced transaction costs of marketing RES electricity	RES promotion costs are reduced
	Increased forecasting quality and reduction of costs of procuring balancing energy	
	Competition for efficient marketing forms	
Market-driven production and investment decisions	Competitive determination of RES remuneration	RES expansion costs are reduced
	RES producers become regular market players	

Source: Purkus et al., Energy, Sustainability and Society (2015) 5:12

Renewables support levy (green fee)

Renewables support levy levied on customers (like German EEG-Umlage until July 2022)

$$\text{RES levy} = \frac{\text{RES support payments} - \text{RES marketing revenue}}{\text{Adjusted non-preferred final electricity consumption}}$$

Adjusted final electricity consumption is equal to total final electricity consumption minus:

- Share of electricity consumption of energy intensive industries, which are exempted from the levy
- Own generation (self-consumption), which is partly exempted from the levy

Expenditures for Electricity

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In 2020 €29.6 billion was paid in subsidies in Germany for RES.

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019*
Gesamtausgaben (in Mrd. Euro)	**65,6**	**68,6**	**69,5**	**76,6**	**76,0**	**75,3**	**74,2**	**75,1**	**79,2**	**81,0**
Staatlich induzierte Elemente	**21,9**	**27,9**	**28,5**	**35,6**	**37,9**	**37,1**	**38,5**	**40,6**	**40,3**	**39,8**
Davon:										
Mehrwertsteuer	4,7	4,9	5,1	5,6	5,7	5,8	5,7	6,0	5,9	6,1
Stromsteuer	6,4	7,2	7,0	7,0	6,6	6,6	6,6	6,9	6,9	6,7
Konzessionsabgabe	2,1	2,2	2,1	2,1	2,0	2,1	2,0	2,0	2,0	2,0
EEG-Umlage	8,3	13,4	14,0	19,8	22,3	22,0	22,7	24,4	24,2	22,5
Umlage nach KWKG	0,4	0,2	0,3	0,4	0,5	0,6	1,3	1,3	1,1	1,0
Offshore-Haftungsumlage und Umlage für abschaltbare Lasten	-	-	-	0,7	0,8	0,0	0,2	0,0	0,2	1,5
Staatlich regulierte Elemente	**15,2**	**15,4**	**16,5**	**18,1**	**17,9**	**18,0**	**18,8**	**20,8**	**19,9**	**20,2**
Davon:										
Netzentgelte Übertragungsnetz	2,2	2,2	2,6	3,0	3,1	3,5	3,8	5,3	5,7	4,9
Netzentgelte Verteilnetz	13,0	13,2	13,9	15,1	14,7	14,5	14,9	15,5	14,2	15,3
Marktgetriebene Elemente	**28,5**	**25,3**	**24,5**	**22,9**	**20,2**	**20,2**	**16,9**	**13,7**	**19,0**	**21,0**
Davon:										
Marktwert EEG-Strom	3,5	4,4	4,8	4,2	4,1	4,7	4,3	5,9	8,0	7,3
Erzeugung und Vertrieb	25,0	20,8	19,7	18,6	16,0	15,4	12,6	7,8	11,0	13,8

Source: Monitoring-Kommission, 2021

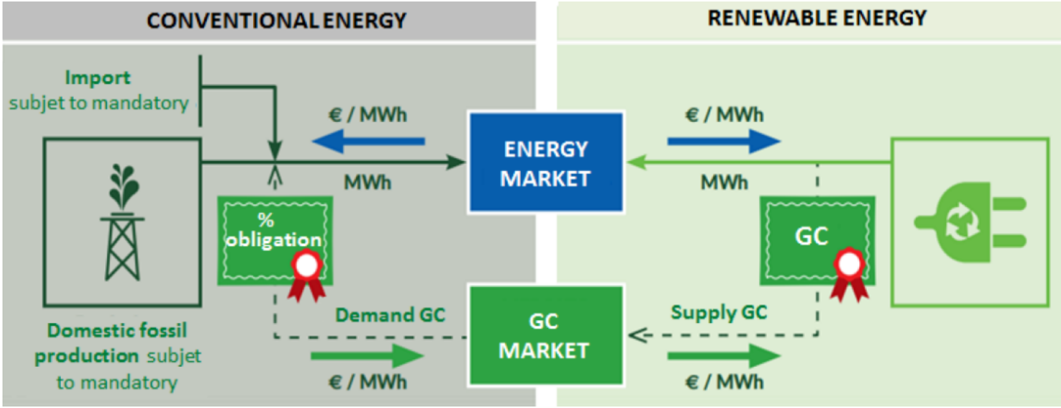
RES support mechanisms: Green Certificates (GC)

For countries with quotas for RES share (either government mandated like the Renewable Portfolio Standard (RPS) in the US) or voluntary corporate targets), they can trade **green certificates (GC)** or **guarantees of origin (GoO)**.

- Fossil fuel-fired generators are required to replace every year a certain percentage of their energy production with RES or to purchase GC from suppliers with excess RES.
- The balance between demand (from generators and importers under the GC obligation) and supply (RES generators) determines the GC price.
- The charges linked to the GC are translated to the final customers through the electricity price (on wholesale or retail market). NB: No external subsidy required!

Guarantees of Origin are a certificate or a piece of paper, that provide proof that electricity has been generated from renewable energy sources. It specifies the generation type, the year it was produced, the location and type of the asset and country and date of issuance. Typically one GoO corresponds to 1 MWh.

Green certificates



Corporate green goals: via green certificates or PPAs

For corporate buyers who want to show they cover their demand with green or clean energy, they can purchase **guarantees of origin** for green electricity and show they cover their demand.

But this doesn't necessarily lead to new capacity being built - they could just relabel electricity that is otherwise subsidised.

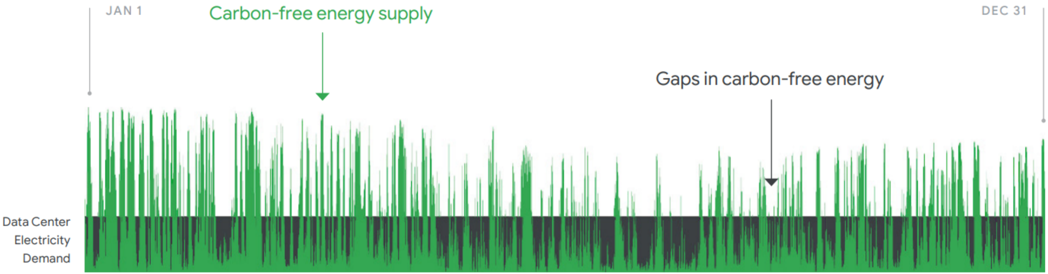
For true **additionality** they can buy **Power Purchase Agreements (PPAs)** where they either build their own plant or offer a wind or solar developer a fixed €/MWh price for their electricity, removing the generator's price risk (like a CfD or swap).

But this only meets demand on an **annual basis** and might be in a different grid.

New ideas circulating for **local, hourly matching**, e.g. with wind, solar and storage/CCS/geothermal. Would lead to **hourly guarantees of origin**.

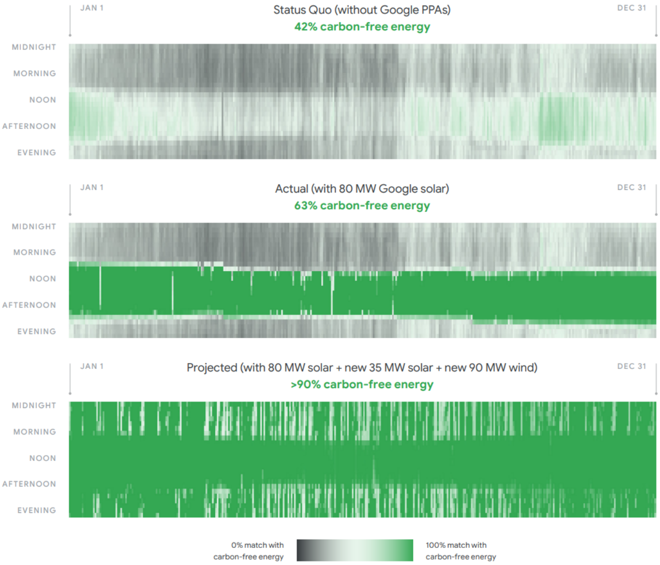
Yearly versus hourly matching

For example, internet firm Google currently matches their data centre demand on a **yearly** basis with renewable energy, but on an **hourly** basis they still have hours when they rely on the fossil-powered grid.



Source: Google 24/7 CFE

Yearly versus hourly matching

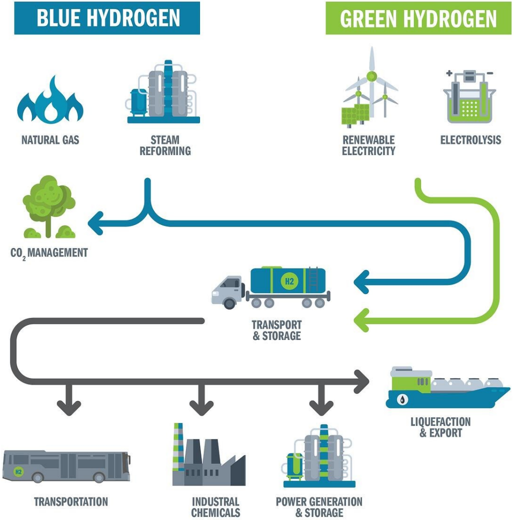


By combining wind and solar, or using storage or dispatchable low-carbon resources, they can improve the hourly matching.

Source: Google 24/7 CFE

Green hydrogen

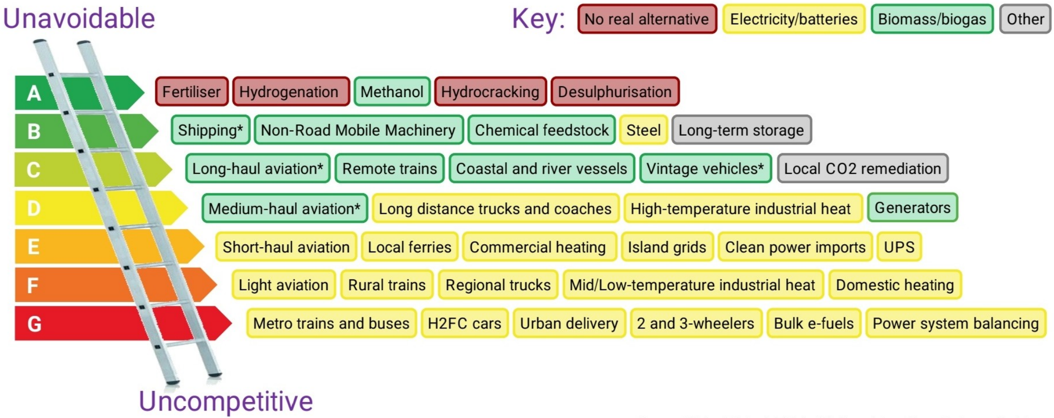
Colours of hydrogen



- Almost all hydrogen today is **grey hydrogen** produced by steam reformation of methane or coal, releasing CO_2 into the atmosphere.
- If the CO_2 is captured and sequestered we have **blue hydrogen** (methane leaks and imperfect capture still mean there is a greenhouse impact).
- Hydrogen produced by electrolysis of water with electricity from renewables is called **green hydrogen** and has no greenhouse emissions.

Hydrogen: the backstop of the energy transition

Hydrogen could help decarbonise sectors where direct electrification is difficult. Some say **champagne of energy transition**; could also say **backstop** for what efficiency and electrification don't reach.



** Most likely via ammonia or e-fuel rather than H2 gas or liquid*

Source: Michael Liebreich/Liebreich Associates, Clean Hydrogen Ladder, Version 4.1, 2021. Concept credit: Adrian Hiel, Energy Cities. CC-BY 3.0

Green hydrogen in Europe: overview

In 2020 the European Commission introduced a target for 40 GW of electrolysers for producing green hydrogen by 2030, both to decarbonise hard-to-abate sectors like steel and heavy-duty transport, and to stimulate Europe's worldwide-leading electrolyser producers.

In 2023 the Renewable Energy Directive III (RED III) set a new sub target for renewable fuels from non-biological origin (RFNBO) of 1% (single counted), and a new target for a 42% share of renewable hydrogen consumption in industry (including non-energy uses) by 2030.

But how do we define green hydrogen?

Source: European Hydrogen Strategy, 2020, RED reform, 2021

Green hydrogen in Europe: definition

There are several factors that have to be addressed in the definition:

- **Renewable**: What do we define as renewable generation?
- **Additionality**: Should the renewable generation be newly built, or can we use capacity built in the past that has already been subsidised? What about generation that has fallen out of subsidy period (like wind and solar older than 20 years in Germany)?
- **Location**: Do the electrolyser and renewable generation have to be co-located, at same grid node, same bidding zone, same country or just same continent? What if there is congestion in the grid?
- **Timing**: Does the electrolyser only consume the same energy as the renewable generation supplies per hour, month or year? Is it sufficient that they just run at the same time?

Green hydrogen in Europe: debate

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There is a **big debate** about the definition of green hydrogen, with environmental NGOs on one side and renewable and gas lobbyists on the other.

If the definition is too **loose**, then some hydrogen could be produced from fossil generators, leading to an increase in emissions compared to hydrogen reformed from fossil gas.

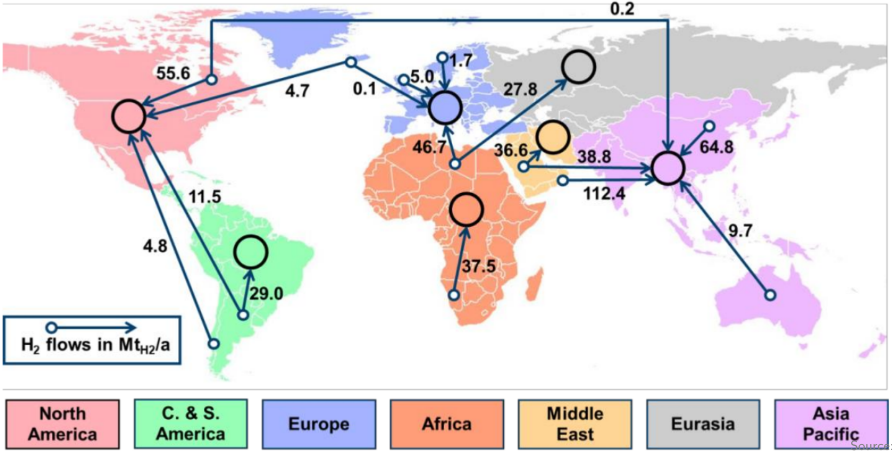
If the definition is too **tight**, green hydrogen installations will be expensive and take years to get built.

Possible **compromise**: for first 5 years allow to co-locate in bidding zones, allow wind and solar from outside subsidy regime, for timing allow it to be green if they run simultaneous and there is monthly energy-matching. Then tighten!

This was regulated in a **Delegated Act** from RED II on renewable fuels of non-biological origin (RFNBO), finalised in 2023.

Worldwide trade in synthetic fuels

Today fossil fuels are traded across the globe. Electrolytic-hydrogen-based synthetic fuels (e.g. hydrogen, ammonia, methane, liquid hydrocarbons and methanol) could also be piped/shipped worldwide. Possible future scenario for hydrogen trade from Helmholtz colleagues at FZJ IEK-3:



Source: Heuser et al, 2020

German H2Global scheme

Technische Universität Berlin

The German H2Global scheme provides support for the production of renewable hydrogen in non-EU countries, to be imported and sold in the EU.

It makes available over €4 billion over 10 years to cover the difference between production costs and what consumers are willing to pay.

This difference is determined by a double auction: producers bids for **hydrogen purchase agreements (HPA)** that run for 10 years, providing investment security, while consumers bid for hydrogen service agreements (HSA) of duration one year.

H2Global was **approved** by the European Commission to comply with EU state aid rules in December 2021. It was topped up from €900 million to €4 billion in 2022. See **H2Global website**.

The EU will also start a €3 billion **European Hydrogen Bank** in 2023.

Source: **ArgusMedia, 2021**