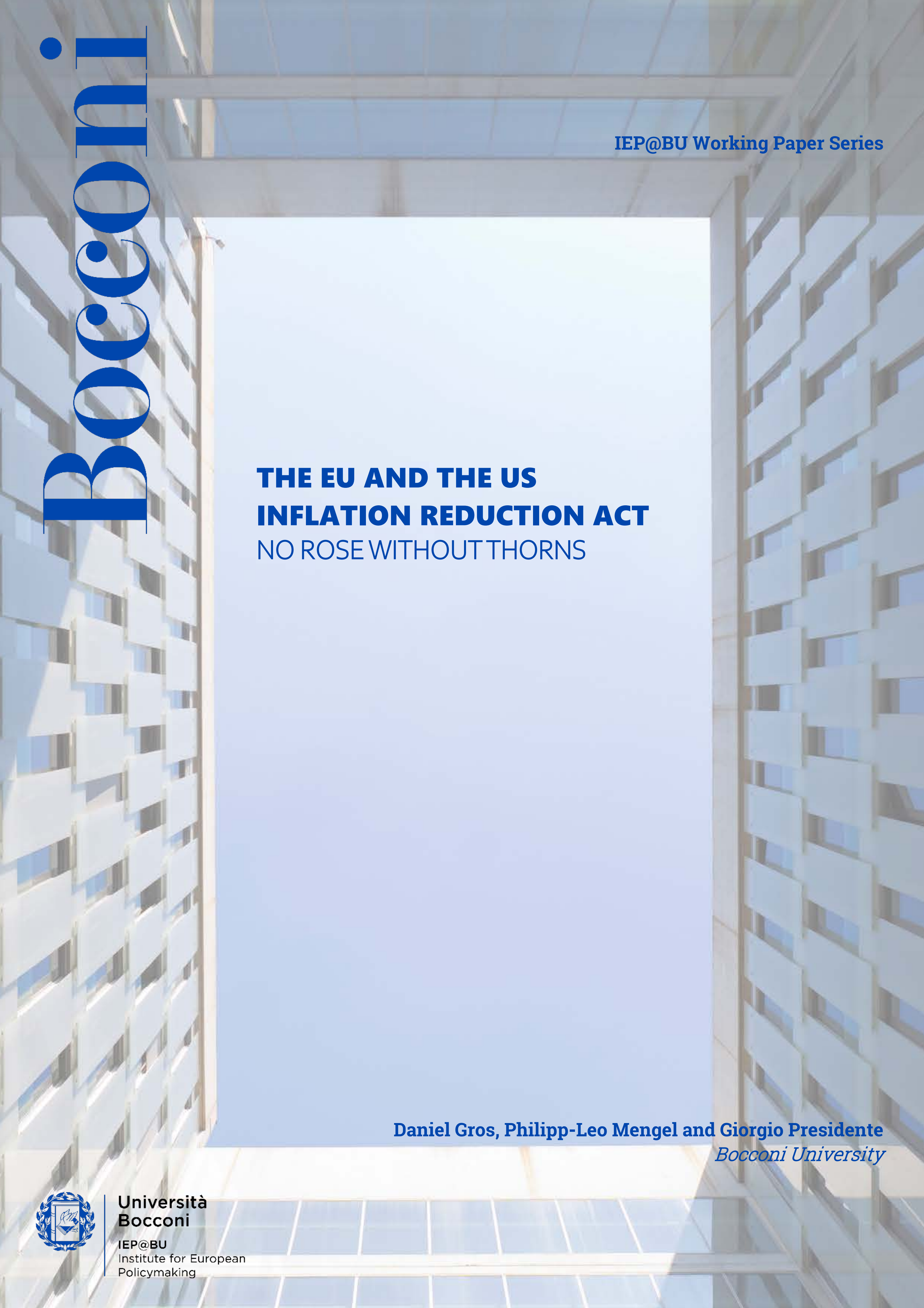

IEP@BU Working Paper Series

THE EU AND THE US INFLATION REDUCTION ACT

NO ROSE WITHOUT THORNS

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EXECUTIVE SUMMARY

The Inflation Reduction Act (IRA) is a vast and complex piece of legislation that has been both over- and under-rated. Its fiscal cost and domestic impacts are likely to be larger than anticipated. But its impact on the EU is very likely to be small and, on balance, positive – thus not validating the supposed need for a European response.

Overall, the opportunities outweigh the disadvantages for European industry since the increase in the potential market for European producers far outweighs the relative handicap created by the local content rules of the IRA, which is small (at most 10-20%) and which can be avoided in the cases of electrical vehicles through leasing.

The only exception is battery production for which the IRA provides heavy, but temporary protection. However, this is a large-volume, low-margin sector which has already received large subsidies in the EU under the so-called European Battery Alliance. Moreover, experience has shown that battery production ends up being close to automobile factories to save on transport costs. There is little danger that a flood of US-made batteries will invade the EU market.

The widely reported budgeted expenditure for the IRA from the Congressional Budget Office (CBO) is cumulatively about $380 billion up to 2032. Our calculations suggest that the overall fiscal cost of the IRA could be much higher, probably over $1,000 billion.

The 10-year total conceals a steep time profile. For the next few years, US fiscal support for renewables will remain low and much below the EU effort for a long time. In terms of green expenditure, the US has years of catching up ahead. However, it will be doing so at a high speed, and has already leapfrogged the EU in terms of an effective carbon price for industry.

At expenditure rates EU support for renewables is likely to amount to much more than the budgeted expenditure of the IRA over the next decade. But most of this will be legacy costs from very high feed-in tariffs promised in the early 2010s.

INTRODUCTION

The Inflation Reduction Act (IRA) which was finally signed into law by President Biden on August 16th, 2022 represents the first major piece of legislation to combat climate change that passed the US House of Representatives. Its name betrays an ambition that might be difficult to realize.[1]

The IRA has had a particularly strong echo in Europe because of its clear intention to give the US leadership in key green technologies using local content provisions that are, in all likelihood, not compatible with WTO rules. This discrimination against imports has ignited a heated discussion in Europe over whether the EU needs to 'respond' to the IRA with similar measures.

In this Working Document, we do not try to provide an overall evaluation of the IRA or its cost-effectiveness with regard to addressing climate change and US emission. Rather, we investigate its impact on the US market and on EU export opportunities, concentrating on the material content of the IRA – not its intention. The most important provisions of the IRA in terms of financial cost and environmental impact concern four areas: Electric vehicles, renewable power, hydrogen, and carbon capture and storage. The IRA also heavily subsidizes the mining of critical materials for battery production. But this is also an area in which Europe, cannot, and perhaps should not, try to compete given its limited deposits and the strong local opposition faced by all mining projects.

There already exist many alternative estimates of the overall fiscal cost of the IRA by a number of highly respected experts (see in particular Bistline, Mehrotra, & Wolfram, 2023), including from financial institutions (Jansen, Jäger, & Redeker, 2023). Most of these estimates are based on agent-based models of how, for example, investors and car buyers would react to the incentives provided by the IRA.

Our approach is different. In each area we simply ask how much production or adoption would have to increase to achieve the goal of the IRA. For example, we calculate by how much renewable energy generation capacity has to increase in order to meet the goal of reducing emissions in the power sector to one fourth of the 2022 level. Another example is the subsidy for electric vehicles (EVs), in the context of the Biden administration's explicit goal that EVs account for 67% of annual US car sales by 2033 (White House, 2023c).

Public discussion has been dominated by the official estimate provided by the Congressional Budget Office (CBO) that the cumulative budgetary cost of the IRA will be $379 billion up to 2032 (CBO, 2022). This figure has to be treated with more than the usual grain of salt. First of all, it represents only an estimate, and one that appears to

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[1] Most of the inflation reduction of the IRA is supposed to come through lower prescription drug prices and lower energy costs once renewables dominate power generation CRFB 2022.

be very much on the low side. Other estimates by investment banks or academics arrive at much higher figures (Bistline, Mehrotra, & Wolfram, 2023; Credit Suisse, 2022).

Our own estimates, based on the official goals of the Biden administration in terms of EV penetration, renewables and hydrogen production, also lead to much higher totals; more than twice or three times the CBO figure.

The 10-year sum and cut-off is customary in US budgeting. It is often useful to illustrate the longer-term costs of policies, but in this case it might be misleading because it neglects the fact that expenditure will increase gradually over time and that the IRA will create obligations for the US federal government that might last well into the 2040s. Our own estimates show that the costs arising after 2032 might be as large as those arising up until then.

Looking at the time profile of expenditure might be more informative. Our calculations suggest that for the next few years the cost of the IRA will remain moderate, but could then increase exponentially, especially if the IRA succeeds in speeding up the green transition in the US.

Looking at the flow of annual expenditure also facilitates the comparison with the EU. We find that US fiscal support for renewables will remain well below the EU effort at least until 2028/29, but from then, could exceed it. The US is thus in most areas not leaping ahead of the EU, rather it is catching up at high speed.

The escalating time path of the cost of the IRA provides a reason to discount the very large cost estimates (including our own) because once these costs become apparent, pressure will mount to rescind some of the more costly or generous provisions of the IRA. This might be the case particularly for green vehicle subsidies which could become very expensive for the Treasury once EV sales take off. In other areas (renewables support, hydrogen, or carbon capture and storage subsidies) it will only be possible to stop further increases in the costs since these schemes create long term (10-12 years) payment obligations for the government. European government had the same experience in the early 2000s when the cost of the very high feed-in tariffs for renewables escalated as adoption increased much more quickly than expected.

The fact that the IRA provides only tax credits instead of subsidies has created some confusion. But the tax credits of the IRA are almost all fully transferable. This means that an entity which receives a tax credit under the IRA, but does not owe enough taxes to use the credit in its own tax declaration, can simply sell it. This means that the tax credits under the IRA are in reality direct subsidies. These subsidies will not appear anywhere in the federal budget, rather they will reduce tax receipts; they represent what the OECD calls 'tax expenditure'.[2]

One widely cited advantage of the IRA is that its provisions are simpler than those of the many renewable support schemes in the EU. This is true to some extent. For example, the production tax credit of 1.5 US cents per kWh is available at the same level throughout the US, whereas each EU country has different support schemes. The subsidy for EV purchases is also simple – but not more so than those existing in Europe.

However, the local content rules and other provisions attached to these schemes (e.g. the need to meet prevailing wage and apprenticeship requirements)[3] will be very difficult to interpret and implement. For example, the amount of the Production Tax Credit is increased by 10% if at least 40% of all manufactured products incorporated into a renewable installation are of US origin. To benefit from this higher rate of support the investor will have to label each item as either a manufactured product or not. Moreover, in many cases it will remain open to interpretation whether a certain product, e.g. whether an inverter, is of US origin when it may have been assembled in the US using imported components. The potential for conflict between the IRS and investors is thus very large.

The remainder of this Working Paper is organized as follows. The next section briefly describes the major subsidy programs of the IRA sector by sector. This is followed by a summary of the potential expenditure paths until 2032 and beyond. Finally, we turn to the overall impact of the IRA on EU Industry by weighing up two effects that go in opposite directions, namely the local content requirements versus the growth in the market.

Four Annexes provide details on the cost calculations, on EU spending compared to the IRA, and the demand model used to estimate the impact of the IRA on European industry.

SLICING THE CAKE

The IRA consists of a number of specific provisions, mostly tax credits, for specific sectors with little interaction between them. We therefore discuss in this section the most important sectors: Electric vehicles, renewable power, hydrogen, carbon capture

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[2] The use of the term 'tax credit' has also caused some confusion in the EU because selective tax credits are subject to state aid rules in the EU. At first sight it might appear that the EU is not able to initiate a similar support scheme as the IRA. However, the IRA subsidies for EVs and renewables are very similar to what is being practiced in Europe today.

[3] Most IRA provisions state a base amount for tax credits which is multiplied by 5 if the investor/operator of a facility meets prevailing wage and registered apprenticeship requirements. Throughout this Policy Brief we assume that investors will always choose to meet these requirements.

and storage, and finally a financially smaller and time limited program to foster domestic production of certain inputs for renewables.

As mentioned above, these provisions are mostly unlimited in terms of time and potential expenditure. We provide an estimate of the expenditure that would result if the US were to reach its own goals in these different areas. This will provide a rough estimate of the potential opportunities for EU producers due to the market expansion generated by the IRA.

Electric vehicles (EVs)

This is the most straightforward element of the IRA. Its provision is time limited (until 2032) but unlimited in amount since it depends on the evolution of the market for EVs in the US.

The basic rule under the heading "clean vehicles" (Tax code: 30D) is simple: The first-time[4] buyer of an EV receives a subsidy of $7,500. This subsidy for EV sales is similar to the schemes run by many EU Member States. However, the subsidy is subject to stringent local content rules. The first condition is that the car must have been manufactured/assembled in North America. However, not all cars produced in North America (CAN, US and MEX have a common automobile market) can benefit from the full $7,500 tax credit. They must fulfil further conditions to qualify for the two elements of the full subsidy:

> $3,750 if at least 40% of the value of certain critical materials used in the car/battery is extracted/refined in North America[5], and an additional $3,750 if at least 40% of the value of the components of the battery is manufactured in North America.

These two provisions provide very strong protection to North American mines or refineries of these critical materials. The value of the critical materials used in EVs has been estimated to be about $1,000-$2,000. This implies that North American miners could dominate the US market even if they are 2-3 times more expensive than imports. Moreover, neither subsidy will be available if any of the components or critical minerals used to produce the battery come from a foreign entity of concern

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[4] The subsidy for second hand EVs is only $4,000.

[5] Formally the condition is that the battery or its components must come from a country that has a free trade agreement with the US. Canada and Mexico participate in the revamped NAFTA called *United States-Mexico-Canada Agreement* (USMCA) and thus satisfy this condition (United States Trade Representative, 2020). Some EU representatives had suggested that the EU could conclude some less ambitious agreement to ensure that EU-made cars could benefit from the EV subsidies. However, this seems to be excluded for the time being. The politically charged nature of these subsidies going to foreign made cars is exemplified by a proposal from the Senate to exclude "idle European allies from obtaining any EV subsidies until they match US commitments to Ukraine" (Cotton, 2023).

(Bond D. , 2022; Bown, 2023). This excludes all Chinese EVs and those with Chinese battery inputs from the IRA subsidies.[6]

A rough estimate of the cost of this provision can be based on the target of the Biden administration to have EVs accounting for at least 50% of all car sales by 2030 and 67% by 2033 (White House, 2023b, 2023c). By 2030 annual car sales in the US should amount to around 15 million, which implies 7.5 million annual EV sales. One year later 8 million units should be reached with an expenditure of $30 billion per year, even if only half of EV sales qualify for the tax credit as we assume. In the Annex A1 we show that the US could follow a similar path to that of Norway in the last decade. The assumption that only half of total EV sales qualify seems reasonable given the various price and income conditions required to qualify for the EV subsidy.[7]

This sector might be particularly relevant for the EU given its considerable competitive advantage in the automotive sector. According to recent Eurostat data, EU exports of EVs amounting to about €22 billion in 2022, are about twice as large as imports of EVs which amount to only €12 billion (Eurostat, 2023).

However, concerns that the Buy American provisions of the EV subsidies could constitute an important market barrier for European exports have been much alleviated by the fact that leased cars sold through leasing arrangements can receive the subsidy even if they are not produced in North America. Given that a large proportion of all high-end cars are anyway sold via leasing this implies that European producers are likely to benefit from the subsidies.

The IRA also contains subsidies for commercial EVs, which also run until 2033. The amount per vehicle reaches up to $40,000. Given the currently nascent market for zero-emission trucks, this provision might appear to be of limited importance today. But European truck manufactures would be well placed to participate in this niche, should the market expand. We have not made a separate estimate of this part of the IRA.

Annex A.1 provides more detail.

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[6] Batteries made in the EU giga factories of Chinese battery producers and used in EU made cars should still be acceptable.

[7] There are income and price limits (cost of car below $55,000 or below $80,000 for SUVs, and family income below $250,000). But some of these limits might be avoided because they do not apply to leased vehicles (Tax code: 45W) and the recent wave of price cuts in the EV sector has made the price limit less binding (IRS, 2023). Also, the income eligibility requirements could turn out to be difficult to enforce as households will soon find workarounds for most eligibility caps. For example, by buying an EV in the name of the kids or next of kin.

Renewable power

Under this section, the IRA provides tax credits for clean energy (really clean electricity) production and investment costs. These subsidies are potentially unlimited in time and amount because this program will end only once a key climate condition is reached, namely that emissions from the US power sector fall to one fourth of the 2022 level, or by 1.8 billion MWh/year.[8]

There are two support schemes; an Investment Tax Credit (ITC) and a Production Tax Credit (PTC). The basic rules are simple:

The **Production Tax Credit (PTC)** provides 1.5 cents/kWh, which is increased by 10% if certain local content requirements are met (+10% if in an energy poor community). This results in about $16.5 per MWh. With 1.8 billion MWh/year needed to reach the goal, this yields an annual cost of about $30 billion once this condition is met. Costs in earlier years might be somewhat lower. However, the cost might have to be paid for a considerable time beyond 2032 because the tax credit is available as long as the US does not reach this emission benchmark for the power sector. Our estimate of the total cost over 10 years amounts to more than $211 billion. Since the subsidy rate of the PTC is inflation indexed, the nominal amount is thus likely to be much higher than 1.5 cents by 2030. Our estimates should thus be viewed as being expressed in real terms.

The **Investment Tax Credit (ITC)** provides 30% of the total cost of investment, which increases to 40% for local content (all iron and steel and 40 % of manufacturing inputs). Simple back-of-the-envelope calculations[9] for the Investment Tax Credit arrive at a similar order of magnitude, namely about $230 billion.

Our calculations should be viewed as conservative since other parts of the IRA and the trend towards electrification of the economy should increase overall power demand.

Higher power requirements from EVs should not be the main problem since EVs use surprisingly little electricity (only about 4 MWh/year because they are much more energy-efficient than internal combustion engine powered cars). The IEA (2020) estimates that by 2030 the demand for electric power by EVs in the US could amount to about 150 billion TWhs. Power demand from EVs would increase the total by less

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[8] The goal for 2035 is a carbon neutral power sector by 2035 (White House, 2023b).

[9] We use a similar reasoning as for the PTC: assuming that 1 MW of installed capacity of Wind yields approximately 4,000 MWh/year implies that the required increase in wind power capacity (if all wind power) is 450,000 MW. The cost per MW installed can be assumed to be $1.3 million, which implies total investment needs in this sector of $585 billion. Since the ITC provides a subsidy of 40% this leads to a total cost of about 230 billion.

than 10 %. However, the production of green hydrogen and carbon capture and storage, as discussed next, could lead to a more substantial increase in power demand, increasing the cost of the clean power subsidies (and increasing also the market size for EU producers).

Annex A.2 provides more detail.

Hydrogen production

Under the Clean Hydrogen Production Tax Credit, the IRA also provides a subsidy for the production of hydrogen, which is limited in time, but potentially unlimited in amount if hydrogen production takes off.
The provision is very simple: The government provides a subsidy of $3 per kg of hydrogen produced for ten years once the facility starts operating. This subsidy will be available for all facilities that start operating before 2033. There are no local content requirements. EU manufacturers of the machinery needed for CCS should thus see their sales increase.

A rough estimate of the total cost (and thus the potential market) can be obtained by using the official US target for H_2 production, which sees production increase by more than a factor of 10 by 2030.

Annex A.3 provides more detail.

Carbon Capture and Storage (CCS)

The IRA provides several different subsidies for the capture and storage of CO_2 for any new facility.[10]

The most important element of the CCS tax credit is a subsidy of $85 per ton captured from industrial processes or power generation. [11] This tax credit is interesting because it provides a clear incentive for producers of carbon intensive goods, like cement or steel, to capture the CO_2 that is created in their installations. Capturing CO_2 in this way should be much easier than by direct air capture because the concentration of CO_2 is much higher.

The $85 per ton of CO_2 incentive of the IRA will provide a real-life test of the cost of CCS. Estimates of the cost of CCS vary widely from case to case with many lower

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[10] The most ambitious one is a $185 per ton subsidy for direct air capture. However, such direct air capture technology has so far been attempted only on an experimental scale with very high costs and capturing only 10,000 tons of CO_2 annually on average (Ozkan *et al.* 2022). It is uncertain whether $185 will be enough to cover the costs at a larger scale.

[11] The subsidy of $130 for use in oil recovery for 12 years is very much contested and might be of lesser importance.

than $85 per ton. Industrial CCS has not performed well so far.[12] Of the 27 existing operations only 11 are industrial facilities, capturing just 7 MTPA of carbon dioxide. However, the IRA provides a radical innovation as it is the first time that investors can count on a generous subsidy, guaranteed for a long period of time which might kickstart the sector (Financial Times, 2023b), given some more optimistic cost estimates (IEA, 2021), and the fact that the subsidy will be paid for 12 years.

The success and fiscal cost of the subsidy for CCS is thus difficult to predict. One benchmark might be for US industry to achieve a 2% reduction in emissions annually through CCS (similar to the EU's target reduction under the Emissions Trading System [ETS]).

US industry emits about 1,600 billion tons equivalent per year. At unchanged production and technology levels, a reduction of 2% per year would require additional CCS facilities capturing 32 MTPA. The corresponding fiscal cost would thus be about $2.5 billion for the first year, increasing by this amount every year for 12 years (i.e. $5 billion year two, $7.5 billion year three and so on). After 12 years the annual cost would reach $30 billion, with a reduction in annual industrial emissions of around 24%. The total, cumulative cost for the first 12 years would amount to around $100 billion. This is of course only an illustrative calculation, not a prediction. But it provides an order of magnitude of the potential cost (and thus the market size) if CCS is to make a significant contribution to abatement. As with hydrogen, there are no local content requirements.

The detailed calculations can be found in **Annex A.4**.

Pure protectionism: Support for US green tech

The IRA also contains a section called Advanced Manufacturing Production Credit whose purpose is to support "domestic manufacturing of components for solar and wind energy, inverters, battery components, and critical minerals".
Given that this provision specifically concerns some rather limited sectors we do not provide cost estimates. Moreover, support is limited in time to seven years (2023-29)—then phases out—which implies that it might lead to a short-lived boom in investment in production (potentially with only the assembly of the various inputs subsidized by this part of the IRA). Even in the US it takes some years to build a new factory, find specialized workers and then ramp-up production. The number of years remaining before the end of this credit is not that large (e.g. production starting in 2025, subsidy ending in 2029). It would thus not be surprising if one were to observe a rush to set up new production facilities in the short term.

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[12] A global study by the Institute for Energy Economics and Financial Analysis in 2022, finds:

> *"There are 27 commercial-scale fossil fuel-based CCS facilities (compared with thousands of renewable projects) in operation. These facilities only capture around 40 million tonnes per annum (MTPA) of CO2 and generally have not yet performed as expected"* (Salt, 2022).

Linked to this Advanced Manufacturing Production Tax Credit are the local content requirements (LCRs) for batteries and critical materials which are also part of the EV tax credits. These conditions, however, will be difficult to implement. It is inherently difficult to determine with precision how much of any critical material is incorporated in a car because one would have to follow the entire supply chain for the hundreds of components from which an electric vehicle is build. Moreover, it is inherently arbitrary to determine the value of a mineral incorporated into any complex manufactured good because one needs to determine a benchmark for each mineral.[13] One needs a cheat sheet to keep track of the 50 odd critical minerals and dozens of components of wind turbines or photovoltaic installations (Bell *et al.* 2023).

The two conditions for the Clean Vehicles Tax Credit regarding critical minerals and the battery imply very high rates of protection (if they become binding). For example, the costs of a battery pack for an average EV amount to around $15,000 today. A subsidy of $3,750 implies a degree of protection of 25%. The effective degree of protection is even higher if the car also qualifies for the second $3,750 subsidy by only using minerals sourced from the US. The cost of raw materials for EVs (of which these critical minerals constitute the bulk) has been extremely volatile going, according to one source, from a low of $1,875 in 2020 to a high of over $8,255 in 2022. In the middle of this range a subsidy of $3,750 provides a rate of protection of 100%.

These very high rates of protection naturally imply very high costs for the LCRs—also with regard to general welfare. With a tariff as the instrument of protection, the government obtains revenues which can then be re-distributed. By contrast, LCRs yield no revenues. This implies that LCRs might have much higher welfare costs than tariffs (per unit of tariff equivalent).

In 2022, shipments to the US accounted for 26% of total EU export of batteries.[14] However, batteries accounted for only 4% of total EU export value in 2022, which implies that the US market for batteries accounts for only 0.1% of EU exports. It is doubtful whether the IRA subsidies for the production of batteries and components will have a lasting effect and, more importantly, whether they make economic sense given the size of the market and low margin nature of this sector (Financial Times, 2023a).

Trade in batteries and their components, is already distorted. The US has a 3.4- 3.5% tariff in place for all types of batteries. Similarly, the EU has a duty rate of 3.7% on lead-acid batteries and a 2.7% rate (reduced to 1.3% due to autonomous suspension)

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[13] For example, for copper the question is whether one should determine the value of the metal in a car by (1) looking at the kilos of refined copper (with a certain purity) that went into the production of various components, or (2) the copper wire used, or (3) the amount of copper ore that constituted the starting point for the copper or copper wire.

[14] Batteries are included in the Harmonized System (HS) 2012 code: 8507 - Electric accumulators, including separators therefor; whether or not rectangular (including square).

on lithium-ion batteries. Furthermore, the EU is subsidizing battery production via the European Battery Alliance, launched already in 2017 that receives substantial state aid, about 6 billion euro so far, which according to the Commission crowed in 14 billion in private investment, implying a subsidy rate of over 40%.[15]

The dynamics of the fiscal cost over time: the price of a successful green transition

Figure 1 below shows our estimates of the annual cost of the four major subsidy programs that are likely to have the largest fiscal impact. These cost estimates assume that the major targets in terms of EV market penetration, renewable power generation, green hydrogen production and CCS will be reached. Therefore, these estimates show the (fiscal) cost of success. Very high feed-in tariffs were stopped in Europe when their cost became apparent. Solar feed-in tariffs, guaranteed for 20 years, started at about 60 euro cents per kWh (40 times higher than the IRA subsidies under the PTC). It remains to be seen whether the political dynamics will be similar, given that some of the subsidies create interest groups that are geographically concentrated (e.g. renewables mainly in thinly populated States that lean Republican).

The EU started its support for renewables much earlier, when the cost of solar was ten times higher than today. Moreover, the length of the support (20 years) means that even today it is close to 80 billion per year, much higher than the fiscal cost for renewables we project for the IRA, which would reach only 30 billion per year if the decarbonization goal is reached. The key point is that most of the cost and the expansion of the market will occur gradually over time.

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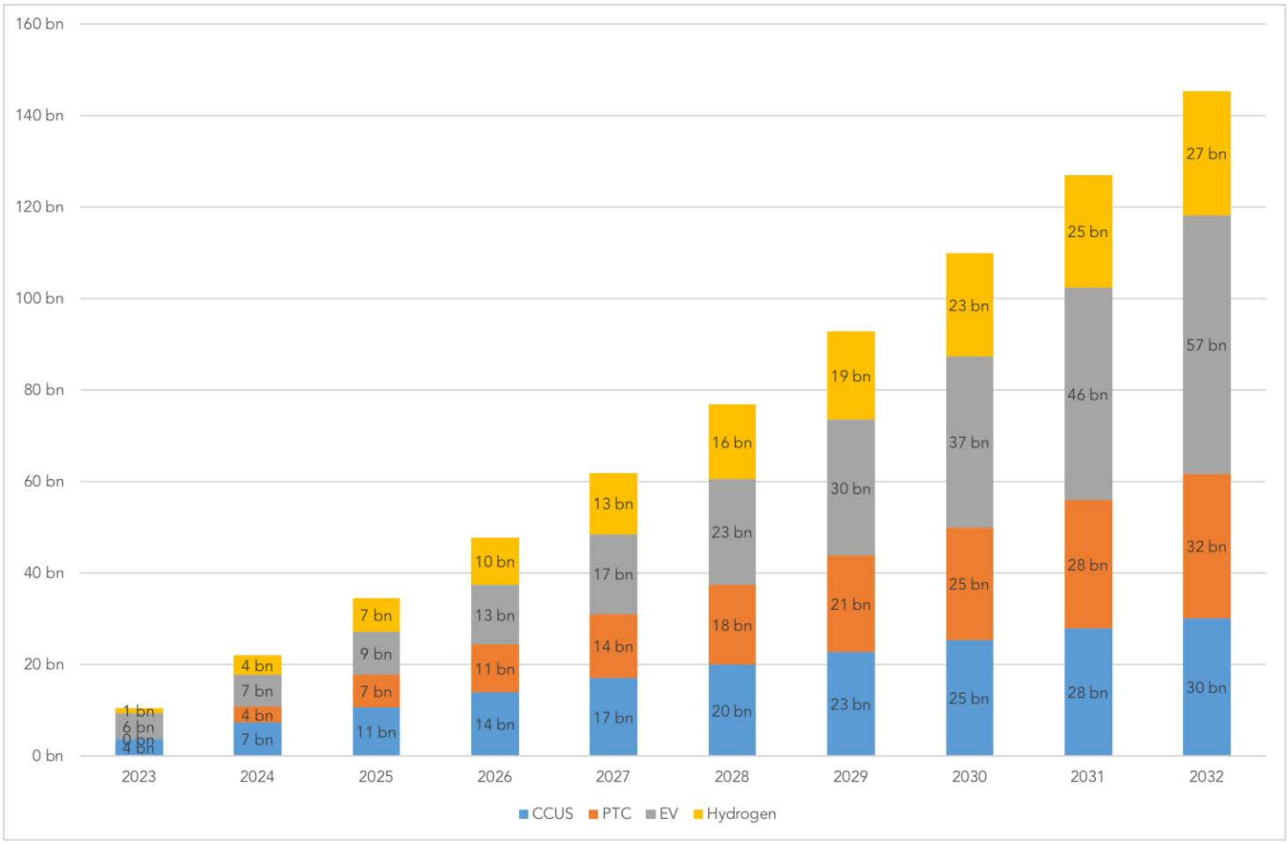
[15] https://ec.europa.eu/commission/presscorner/detail/en/speech_23_1327

FIGURE 1 *Annual costs of the four major IRA subsidy programmes*



Source: authors own estimates based on Biden’s targets

THE OVERALL IMPACT FOR EU INDUSTRY: LOCAL CONTENT VERSUS MARKET GROWTH

There are two effects of the IRA that affect the interests of EU industries which hope to export to the US. On the one hand, the Buy American provisions of the IRA disadvantage EU exports. But, on the other hand, as discussed in the previous section, the size of the market increases – thus creating opportunities for EU exporters and potentially also for investment in the US. We start with an evaluation of the impact of the local content requirements on trade.

Buy American in the IRA and the price handicap of EU producers on the US market

The 'Buy American' provisions contained in some parts of the IRA are not unique. Local content requirements have a long tradition (and are usually regarded as being costly and ineffective (Stone et al., 2015).

The key question is what advantage US producers derive from the Buy American provisions of the IRA. One way to answer this question is to translate them into tariff equivalents, i.e. the tariff that provides an equivalent degree of protection to domestic manufacturers.

For **EVs** this is straightforward at first sight: Only cars produced in North America qualify for the subsidy of $7.500 for a car costing $55,000, suggesting a tariff equivalent of about 15%. However, in reality the true handicap facing European producers is likely to be much lower. The first reason is that for SUVs, vans and pickups the price limit is $80,000.

Among the foreign manufacturers on the list of eligible models published by the US government in early 2023 (DOE, 2023) the majority are from the EU and for most models the maximum suggested retail price (MSRP)—i.e. the highest price to qualify for the subsidy—was $80,000, which means that for most of the models sold by EU producers the subsidy represents a cost disadvantage of less than 10%.

This suggests a cost handicap or tariff of only about 10%. However, the fact that the car is made in North America is only a first condition. The battery and raw materials used in the production of the car must satisfy local content thresholds to receive the two halves of the subsidy of $3,750 each. Satisfying these LCRs implies additional costs that European produced cars do not have to sustain. The real handicap for foreign producers is thus less than $7,500, or 15%, depending of the extra cost of sourcing batteries and components locally. For example, if it were to cost $1,500 more to source North American critical materials and batteries, the effective subsidy would be reduced to $6,000, or only 7.5% for a SUV costing $80,000.

Finally, one has to take into account that EVs that are bought for leasing qualify for the tax credit but are exempted from the LCRs.[16] Leasing accounts for a significant proportion of the US market (IBISWorld, 2023), and the American auto industry expects it to increase up to more than half of the total EV sales over the next years.

All in all, one must conclude that the price handicap for cars produced in Europe is low, almost certainly below10%.

For **Renewables** the calculation becomes somewhat more involved and one has to distinguish between the two types of subsidies offered for zero emission power generation: PTC and ITC.

For the **Production Tax Credit (PTC)**, as mentioned above, the subsidy amount increases by 10% if a certain minimum share of the manufacturing parts of the installation are US-made. This minimum LCR starts at 40% and then increases over time to 55% by 2027.
Some sources (e.g. Houser *et al.* 2023) claim that most existing US wind projects that pre-date the IRA already satisfy this 40% domestic content requirement, which would thus be irrelevant.

For an investor using the required percentage of US inputs the condition increases the tax benefit by 10%. The question then is by how much does the cost of construction have to increase to lead to the same financial result as when non-US inputs are being used. This point is reached when the share of the PTC in total revenues times 10% is equal to the increase in cost due to the use of local inputs. The price handicap for foreign suppliers is less than 10% because satisfying the LCR increases only part of overall revenues. For a project in which the expected production tax credit amounts to one half of total revenues, local inputs will be used only if they cost less than 5% more than European ones (or generally foreign ones).

For the **Investment Tax Credit (ITC)** the calculation is somewhat different. An investor will be indifferent between using foreign inputs or domestic ones if the after-subsidy cost of the project is the same, i.e. if 70% of the cost without domestic inputs equals 60% of the cost using domestic inputs, or if the cost ratio is equal to 7/6 = 1.166. In other words, US inputs would be used even if they were 17% more expensive.[17]

Calculating the break-even point at which investors become indifferent between satisfying the LCR and using only imported inputs becomes somewhat more difficult

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[16] This was formally confirmed by the Internal Revenue Service (IRS, 2023). See also Aghion et al. (2023), Chapter 9.

[17] The increase of the tax credit from 30 to 40% might give the impression of an increase in the tax benefit of one third, potentially offsetting a higher domestic input cost of one third. But the fall in the net of tax benefit cost is from 70 to 60%, a fall of only 16%.

when less than 100% of US imports are sufficient to qualify for the higher subsidy rate. Initially, the required domestic content to qualify for the additional 10% is only 40%. This implies that that effective rate or protection, as usually calculated is higher. For example, one can consider a project with a total cost of $100 using only imported components that qualifies for a $30 tax credit and which has a net cost of $70 to the investor. Increasing the local content to 40% allows the investor to claim 40% of the higher cost, which could increase to $116.6 and still yield the same net cost (0.6*116.6=$69.96). But this means that imports costing $40 could be substituted by domestic production that costs $56.6, or over 41% more. In other words, US producers of some inputs could compete with imports even if they were 40% more expensive.

However, this 41% effective rate of protection is relevant only for US producers, not for EU exporters because it applies only to 40% of the total cost. The weighted average rate of protection facing EU producers is zero for 60% of the cost and 41% for 40% of the costs, remaining thus equal to the 16.6% mentioned above.

The effective rate of protection for EU producers decreases over time as the required local content increases. But throughout this period transition period for the LCRs the weighted average the tariff handicap of European producers remains below 10% (for the PTC) and 17% (for the ITC).

We can compare these rates of protection with those enjoyed by EU producers of renewables components. Using a list of 6-digit HS codes from a report of the International Centre for Trade and Sustainable Development (2008), reveals that many components used to build solar and wind facilities have positive duty rates applied to inputs produced in the United States. For instance, roller bearings, aluminum components and some kinds of photovoltaic cells have duty rates in the range of 6-8%, tubes and pipes made of copper and brass 4.8%, and glass mirrors 4%. Therefore, while the tariff handicap for EU producers due to the IRA is higher than that currently faced by US producers importing European renewable components, the EU market is not fully exposed to US competition either.

The impact on investment?

It could be argued that despite the relatively low tariff handicap—as discussed in the previous section—the IRA might have a negative impact on the EU because EU industry might decide to produce in the US instead of exporting from the EU.

Two related academic literatures—the *proximity-concentration trade-off* and *tariff jumping* literature—speak to this issue. They both consider the problem of a firm deciding whether to serve a foreign market by exporting or by horizontal FDI (either greenfield investment or acquisition).

For instance, in the framework developed by Helpman, Melitz & Yeaple (2004), the probability of horizontal FDI *increases* with trade costs, such as the tariff equivalent of LCRs, and industry productivity dispersion (e.g. presence of superstar firms), but *decreases* with the returns of scale in production.[18] For instance, if production is characterized by large fixed costs, but low variable costs, then firms are more likely to export than to undertake FDI. High fixed costs seem to characterize many green goods.

Predicting whether EU firms will export or relocate to the US requires measuring a number of key parameters and we do not attempt to do that here. However, we notice that the relationship between trade costs and the choice between exporting or foreign investment is not as clear cut as it appears in the current debate.

For instance, game theory arguments suggest that one has to consider market structure (Motta, 1992). Specifically, when a EU firms takes into account that it will have to compete with US domestic firms, it is no longer true that the profitability of foreign investment monotonically increases with the expansion of US market size (induced by the IRA) or with the size of shipping costs.

It is interesting to note that, to the best of our knowledge, neither the proximity-concentration trade-off literature nor the tariff jumping literature examine the case of a full-fledged relocation, i.e. the case of an EU firm shutting down its EU plants altogether to relocate to the US. This seems indeed odd, because investment in the US might be expected to increase *relative* to the EU but seems unlikely to decrease in *absolute* terms. One also has to take into account that it takes more than 3.5 years to build a plant, and EV subsidies are limited to 2032, leaving only a few years to benefit from protection through the IRA.[19] Moreover, almost 30% of automobiles produced in the US already come from EU-owned plants (ACEA, 2018), which limits the scope for further EU foreign direct investment due to potential bottle-neck in the inputs market.[20]

But the key reason why EU-based companies still want to serve the EU market with domestic production is that serving the EU market from the US is costly because the EU imposes a tariff of 10% on imports of EVs (against only 2.5 % for the US, Bown 2023).

Renewables—in particular wind and solar energy—are not tradable due to the large iceberg costs involved in shipping energy products. In this case, relocating would imply fully giving up their EU market. So, we do not expect incumbent EU producers of clean energy to leave the region. However, given that the subsidies for renewables

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[18] Intuitively, if producing a good has constant returns, it is suboptimal to fragment production.
[19] For example, the construction time for the VW/Audi factory in Tianjin (starting 2015) was 3.5 years, for the VW Chattanooga plant (starting 2019) 3.5 years and for the Tesla Grünheide plant (starting 2019) 2.5 years.
[20] The figure refers to 2018 and it goes down to 15% if one excludes Fiat-Chrysler.

are potentially unlimited in time, we expect clean energy producers to open new plants in the US.

Finally, historical evidence casts doubts on the possibility that the IRA will drain resources from the EU. In 2017, the US administration passed an aggressive corporate income tax reform which decreased the rate from 35% to 21%. And yet, research from different sources suggest that the cut did not increase inward foreign direct investment (FDI) in the United States (e.g. Matheson *et al.*, 2022; Djankov and Zhang, 2020).

A chief candidate explanation for the lack of impact is the presence of uncertainty, which has been shown to be negatively correlated to investment (e.g. Bloom, Bond, & van Reenen, 2007). In particular, if the cost of the IRA is discovered to be unsustainable, future administrations might decide to cut the subsidies, which would be an issue for firms that relocate.

More broadly, recent evidence based on a survey among leading economic experts worldwide shows that a large majority of survey participants believe that is unlikely that firms will relocate in response to the IRA (Gründler et al. 2023). The only exceptions are France and Germany, where the majority of respondents express concerns about the future location decisions of domestic firms.

Increase in market size

Having discussed why a relocation of economic activity towards the US at the expenses of the EU is unlikely, and more generally that we do not expect EU investment to decrease in absolute terms, we now consider the possibility that the IRA will *benefit* EU producers due to the increase in market size that the IRA could bring about. This increase is likely to be very large given the cost of success we estimated in the previous sections.

On the one hand, the tariff equivalent imposed by the LCRs will tend to reduce demand for EU goods. On the other hand, the expected increase in the market for EVs and tradable components, including those used for renewable generation, might actually generate positive spillover and increase demand for EU products.

For EVs this is again straightforward. In 2022, about 1 million EVs were sold in the US. If the US follows the trajectory of Norway (with a lag of ten years) this would increase to roughly 7 million in 2030 as mentioned above, representing a 600% increase.

For renewables it is also straightforward to establish an order of magnitude for the increase in market size. For example, the average annual additional installed capacity of solar and wind energy has been about 20,000 MW over the last ten years. However, what is necessary is a total installed capacity of 809,000 MW by 2032, or a rate of new capacity of about 89,000 per year. This would represent more than a threefold increase (345%) compared to the recent path.

This large increase can be achieved only with a massive increase in investment. European developers of wind and solar installations are already very active on the US market and will certainly benefit from this huge expansion of the market even if their projects do not use mainly EU products.

The net result: Increase in market size versus price handicap

The simplest way to determine whether the increase in market size can offset the price handicap for EU producers on the US market is by positing a standard demand curve for the good in question, for example, EVs.

Annex B provides a simple model assuming that the two key elements determining demand are market size and the tariff equivalent of LCRs, which are linked by the elasticity of demand. [21]

Post-IRA exports (from the EU to the US) will be higher if the proportional increase in market size is larger than the tariff equivalent of the buy American provisions multiplied by the elasticity of demand.[22] This appears to be the case for most tradable goods – including EVs – and a wide range of demand elasticities empirically documented by the literature.

The annex provides a brief survey of the demand elasticities for EVs, which with one exception, are in the range of (minus) 1 to 2. Even the upper limit of this range implies that the market for EVs would need to grow only by about 20 % in order for European export opportunities to increase. This condition seems fully satisfied under any scenario.

The results of our simulation suggest that under plausible scenarios, the increase in market size due to the IRA will be large enough to offset the negative impact of the LCRs and so EU producers should be able to greatly increase their exports to the US (provided, of course, that they remain competitive with Chinese producers).

Moreover, there are other sectors for which the market for EU products will expand: e.g. machinery for hydrogen production or CCS. There are no LCRs in these sectors,

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[21] Consistent with our approach to estimate the fiscal cost of the IRA, the model assumes an exogenous increase in demand matching the goals of the Biden Administration.

[22] One might object that the extent of market expansion depends on the demand elasticity too. However, the announcement of restrictive regulation limiting automotive tailpipe pollution, complementary investment in infrastructure, as well as the learning externalities, technology spillovers, and scale effects expected to be generated by the IRA imply that a substantial portion of the increased US demand will be achieved through non-price mechanisms.

which thus represent a pure market opportunity for EU producers of green machinery. Houser et al. (2023) claim that only around 10% of the entire budgeted IRA funding is subject to LCRs that might impact EU exporters.

Other studies have come to different conclusions. For example, Kleimann *et al.* 2023 state that "the IRA will likely harm Europe through its competitiveness effect", without providing any quantitative evidence. EU representatives have tended as well to emphasize that the LCRs of the IRA "create very strong pull factor to move investment and jobs to the US at the cost of partners and allies like the EU" (Vestager, 2022).

Our analysis has centered on the issue of whether the IRA will increase the demand addressed to EU exporters. We find that export opportunities will greatly increase. We do not deal with the question of whether EU (or for that matter US) industry has enough capacity to satisfy this increase in demand.

If EU industry faces serious bottlenecks one would expect it to increase prices and thus profits. This would change the way EU industry benefits from the IRA—via increased production or via increased profits. However, this seems secondary to the question of whether the IRA benefits the EU as a whole.

CONCLUDING REMARKS: WHAT SHOULD THE EU DO?

Looking closely at the various provisions of the IRA reveals that its Buy American provisions are of minor importance compared to the huge step up in terms of climate policy and market opportunities for EU producers. In this sense there is no need for the EU to react to the IRA by engaging in a subsidy race.

However, one needs to distinguish between the interests of the EU overall and those of some industrial sectors and, secondly, between the purely economic impact and the political impact.

We argue that the economic impact for European industry should be positive. [23] Grundler et al (2023) provide a large-scale international expert survey in which the majority share a similarly positive view. But the actual economic impact of the IRA is still to come, while the wider political impact is already being felt today because the mere appearance of US protectionism has strengthened the bargaining position of EU industry to demand European subsidies, supposedly to level the playing field.

A key issue that remains is the transatlantic difference in the approach to climate change: only 'carrot' in the US and at least half 'stick' in the EU. The potentially very high fiscal cost of the carrots (subsidies) in the IRA will become apparent only gradually over time. Vested interest and certain provisions will make it very difficult to reduce the cost once it is discovered.

The elephant in the room is China. The Chinese market alone is larger than the transatlantic one. EV sales in China are much higher (in terms of units) than those of the EU and US combined. Renewable investment in China is also larger than that of the EU and US combined, and China has pledged to reach a renewable capacity of 1,200 GW by 2030, more than double the value the US needs to achieve its decarbonization goal for the power sector. It is thus not surprising that Chinese producers dominate the sectors where economies of scale are decisive.[24] The key issue for Europe's ambition to become a leader in green technology will thus not be the IRA with its minor Buy American irritants, but how to deal with competition from China which, even without explicit subsidies, might be more competitive and, in some areas (e.g. batteries), technologically more advanced.

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[23] We are not the first ones to arrive at this conclusion, see Houser *et al.* 2023, or

[24] See Figure 2.7 in the Energy Technology Perspectives 2023 report of the International Energy Agency (IEA, 2023).

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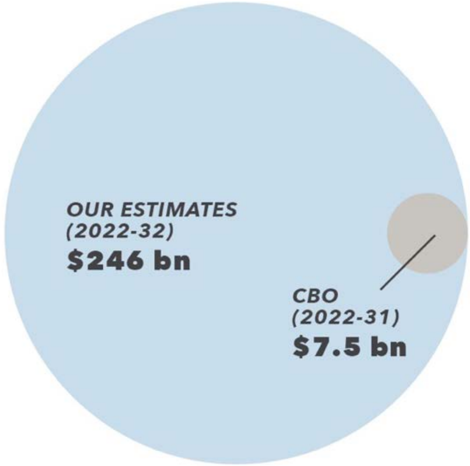
Annex A: Major IRA provisions by sectors

Annex A.1: Electric Vehicles (EV) — Overview

IRA CODE: 13401
TAX CODE: 30D
PERIOD: 2023–2032

The clean vehicle tax credit is provided for purchasers of new electric vehicles. It is only available for vehicles assembled in North America and amounts to (1) $3,750 for vehicles that include critical minerals from the US and FTA countries, (2) $3,750 for vehicles that have their battery components manufactured or assembled in North America and (3) $7,500 for vehicles that meet both requirements. Notably, the respective local content threshold increases over time. For example, for batteries the required percentage of the battery's components being manufactured or assembled in the North America is 50% in 2024 and increases to 100% after 2029. In contrast to most other tax credits in the IRA, the EV tax credit is not inflation-adjusted.

FIGURE 3 *Cost-estimates for Clean Vehicle Tax Credit*



Source: CBO

TABLE 1 *Cost-estimates conditional on the target*

% OF TARGET REACHED	TOTAL COSTS UNTIL 2032
30%	99 bn
40%	120 bn
50%	141 bn
60%	162 bn
70%	183 bn
80%	204 bn
90%	225 bn
100%	246 bn

Two further aspects of the program are noteworthy. First, a new feature called "transferability" allows for the credit to be sold to (third-party) businesses or individuals and makes the tax credit conceptually more similar to a direct-pay subsidy. Second, in theory the IRA imposes certain income caps on the EV tax credit (i.e. $300,000 for couples and $150,000 for singles). However, we argue that in practice these eligibility requirements are difficult to enforce, and households will soon find workarounds for most eligibility caps, for example through buying an EV in the name of the kids or next of kin.

With regard to the projected costs, we assume a quadratic increase in the EV share of total passenger car sales until 2032.[25] From 7.2% in

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[25] A quadratic growth assumption is in line with the Norwegian experience regarding the diffusion of EVs from 2013 until 2023, as suggested by data from OFV (2023). Figure 2 contrasts our EV growth projections with the Norwegian experience from 2013. See also: *https://robbieandrew.github.io/EV/.*

2023 (~1 million EV sales), the White House communicated in a statement from April 17th that it adopts the ambitious target of 50% EV share of total passenger car sales by 2030 and 67% by 2033 (i.e. ~10 million EV sales) (White House, 2023). Assuming that 50% of electric cars are subsidized at $3,750 and 50% at $7,500, this amounts to a $246 bn total subsidy cost until 2032 (Figure 1). This suggests, that even if the USA falls dramatically short of its clean vehicle target, the estimated costs would still be many times the amount estimated in the CBO, as illustrated in Table 1.

Annex A.2: Renewable Energy — Overview

FIGURE 4 *Norway-US comparison: Growth of EV share*

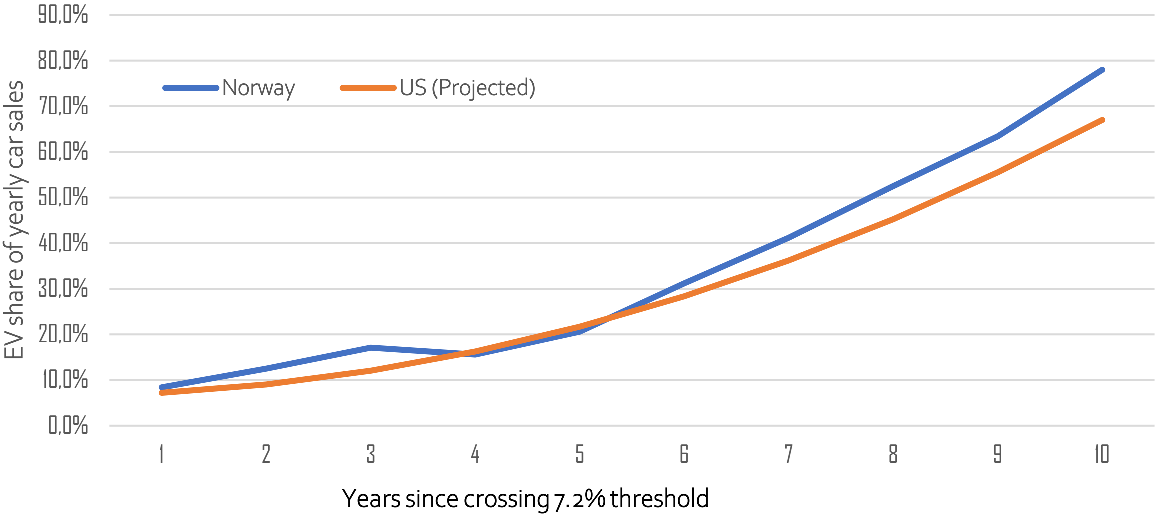
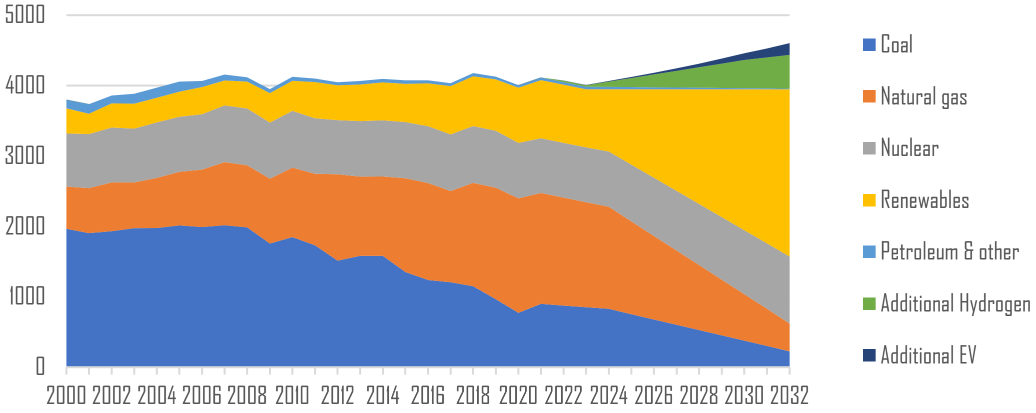


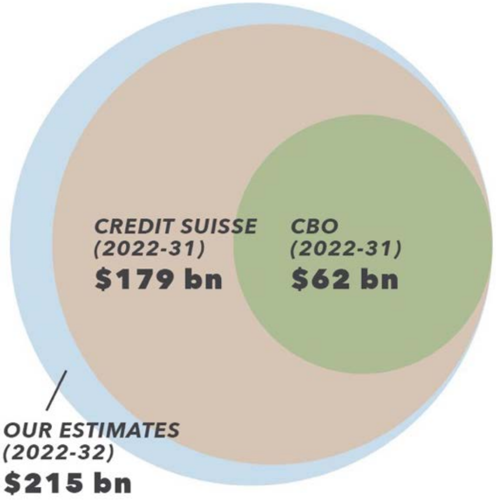
FIGURE 5 *US Electricity generation since 2000*



IRA CODE: 13701 & 13702
TAX CODE: 45Y & 48E
PERIOD: Unlimited. Terminates the later of (1) 2032 or (2) when US emissions from electricity generation reach 25% of the 2022 level.

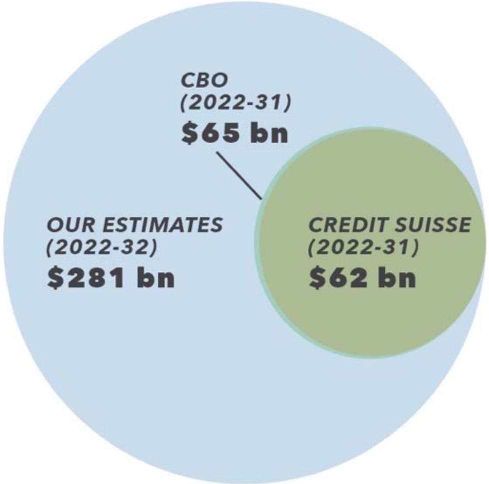
Both the Production Tax Credit (PTC) and the Investment Tax Credit (ITC) are meant to encourage US based production of renewable energy. They provide technological-neutral subsidies for electricity generation from renewable sources (i.e. for which the greenhouse gas emissions rate is not greater than zero) like for example solar, wind, geothermal or biomass, among other sources. The new PTC, introduced in the IRA, replaces the existing production-based (per kWh) tax credit, which was mainly limited to wind. It extends the old tax credit to new energy sources but also offers a more generous subsidy of 1.5 cents/kW which is increased to 1.65 cents/kW for projects meeting local content requirements for steel, iron, and manufactured products, during the electricity generation process. This amount increases by another 10% to 1.8 cents/kW if the facility is located in an energy community. The PTC is available until the condition mentioned above is fulfilled. Once this happens, the subsidy is gradually cut to 70%, 50% and 30% during a three-year phase-out. That means that if, for example, US emissions from power generation reach 25% of the 2022 only in 2040 the full PTC subsidy would be paid until then, followed by lower payments during the phase-out until 2043.

***FIGURE 6** Cost-estimates for Production Tax Credit (PTC)*



Source: CBO, Treeprint Report (Credit Suisse)

***FIGURE 7** Cost-estimates for Investment Tax Credit (ITC)*



Source: CBO, Treeprint Report (Credit Suisse)

Unlike the PTC, which provides a production-based incentive, the ITC subsidizes the actual investment in clean energy generation facilities. It offers a subsidy of 30%, which is increased to 40% for facilities meeting domestic content requirements. Both tax credits are inflation-adjusted and theoretically unlimited in time and amount, as the subsidies only sunset when greenhouse gas emissions from electricity production are cut to 384.4 million metric tons of CO_2 (25% of the total emissions in 2022).

It is highly unlikely that this emission target is reached before 2032 given that the US economy is expected to grow in the meantime and the growth of electric vehicles (EVs) will add to power demand. We thus examine three different scenarios for the US to reach its greenhouse gas emissions goal. The **first scenario** (red dotted line in Figure 2) extends the slow linear trend in emission reductions since 2007. In this pessimistic scenario, the US would need 18 years to reach its target and PTC/ITC provisions would only terminate in 2040. Under the second scenario (yellow dotted line), this would happen in 2035. Finally, under the third most optimistic **scenario** (green dotted line), which assumes a considerable improvement in the emission reduction rate, the subsidy would terminate in 2032, at the earliest possible date.

For the **cost estimates of the Production Tax Credit**, we assume that the required reduction in power generation from fossil fuels is fully replaced by wind and solar renewable energy sources by the end of the respective termination year. Nuclear power capacity is unlikely to expand, and the other renewables sources are too small to make a meaningful impact.

Throughout the eligibility period, the subsidy amounts to 1.65 cents/kWh in real terms. Given the inflation adjustment we do not account for the time value of money. The real interest rate is too low to make a difference. Our estimates should thus be interpreted as approximating the present value of future payments.

Further sources of uncertainty are whether investors will choose the PTC or the ITC and the split between wind and solar power facilities. The PTC is more attractive for wind, which has an average capacity factor of 39%, compared to solar with 17% (IRENA, 2021).[26] These averages hide, of course, very large differences between individual installations but they serve as a rule of thumb to calculate an order of magnitude of the expenditure to be expected. A further useful rule of thumb is that the value of the ITC equals the present value of PTC payments of about 8 years for wind and 11 years for solar power installations. Given that the flow of benefits from the PTC are available only until the terminal condition is met one might expect that investors will increasingly opt for the ITC when that date nears.

Overall, our estimates suggest that the PTC would amount to **$352 bn** under the most pessimistic scenario compared to US$260 bn under the second scenario and **$215 bn** under the **optimistic scenario** where **emissions goals are reached by 2032** (Figure 1). These costs are more than three times the amount currently allocated by the Congressional Budget Office and even exceed other private sector estimates (CBO, 2022; Credit Suisse, 2022).

Regarding our projections for the **Investment Tax Credit**, we assume a 50-50 split between wind and solar power facilities. The assumptions regarding total installed

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[26] The capacity factor is defined as the average output of an electricity production facility over a given period of time.

costs are: $1,300 per kW for onshore wind and $860 per kW for solar panels, following estimates from the International Renewable Energy Agency (IRENA, 2021). Finally, regarding the level of subsidies, we assume that half of the power generation plants meet the local content requirements, i.e. are subsidized at 40%, while the other half are subsidized at 30%, resulting in an average rate of 35% for the ITC. Overall, our estimates suggest that the **total subsidy costs** for the ITC amount to **$281 bn**, with payments ofS$112 bn for wind power facilities and $281 bn for solar power facilities (Figure 2).

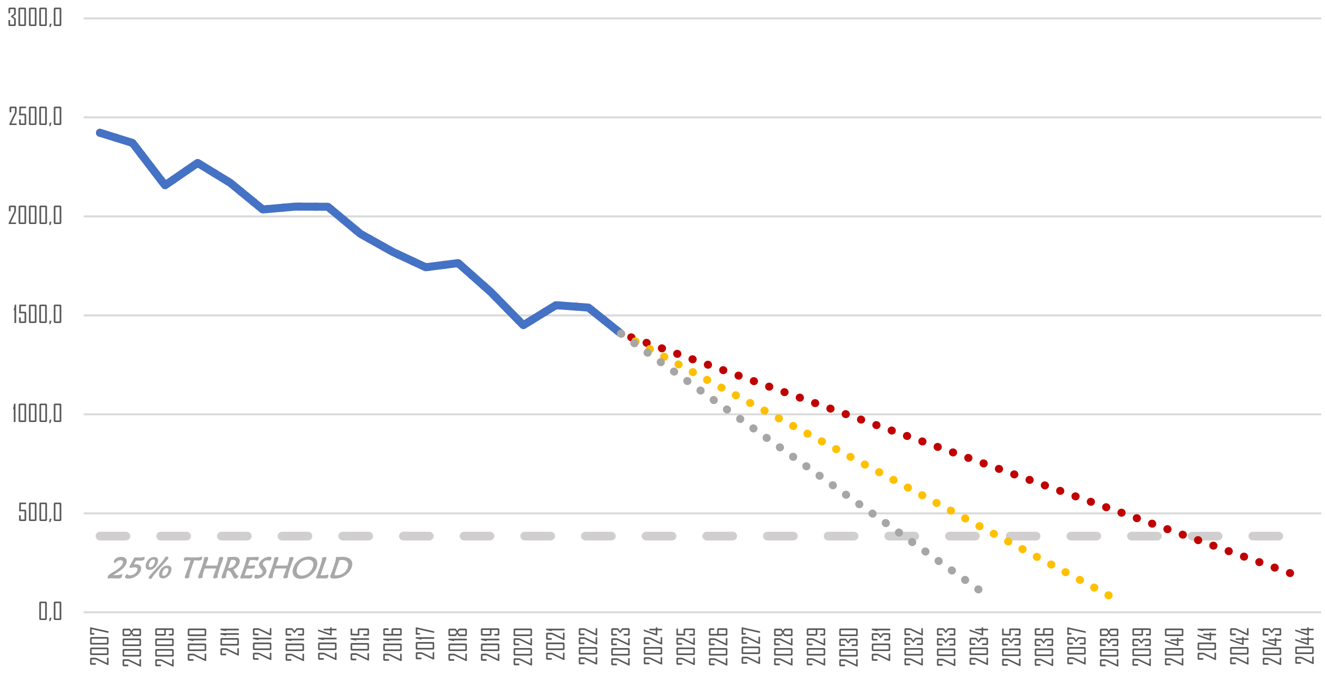
The amounts calculated here will increase if overall electricity demand increases, requiring more investment to achieve the emission goal and lengthening the time period required to achieve the emission reduction goal for the power sector.[27] However, if the price of wind and solar continues to fall even if slower than in the past, the cost will be much lower.

The additional electricity required to power an increasing EV fleet is likely to remain minor since an EV requires about 4 MWhs annually (less in China, see Wu 2021). Even for the 40 million EVs that might be reached by 2032 this amounts to 160 million MWhs (annually), which increases the total additional renewable output required to reach the official target by less than 10%.

A similar calculation can be made for green hydrogen, which requires about 50 kWh per kg, or 50 MWhs per ton (Carbon Commentary, 2021).

The target is 10 million ton (per annum) by 2030, which requires an additional 500 million MWhs (per year). Green hydrogen could thus constitute a much more significant additional demand for (zero carbon) power. Expanding the hydrogen industry could thus mean that the renewable subsidy is required for longer.

***FIGURE 8** CO$_2$ emissions electric power sector*



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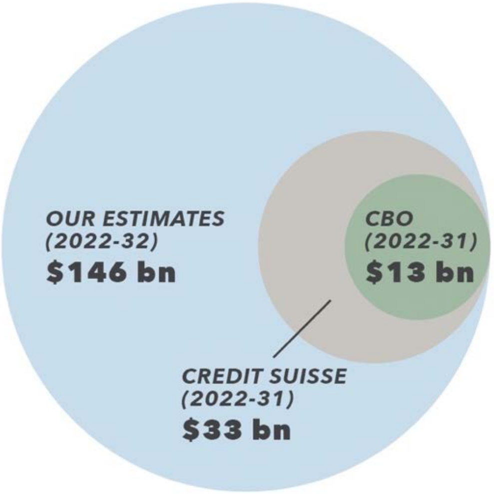
[27] Some estimates of the time required to reach the 25% goal can be found here: https://www.woodmac.com/news/opinion/IRA-tax-credits-for-renewables/

Annex A.3: Hydrogen — Overview

IRA CODE: 13204
TAX CODE: 45V
PERIOD: 2023–2032 (**but** for first 10 years in service, so payments can last until 2042)

__FIGURE 9__ Cost-estimates for Hydrogen Production Tax Credit



Source: CBO, Treeprint Report (Credit Suisse)

The clean hydrogen production tax credit is designed for producers of hydrogen in the United States and amounts to US$3 per kilogram (inflation-adjusted) for facilities producing green hydrogen under prevailing wage and registered apprenticeship requirements. It is available for facilities being constructed from 2023 to 2032 but since it can be claimed for 10 years the tax credit will extend until 2042 in practice.

Overall, the clean hydrogen tax credit is meant to solidify the US competitive advantage in the production of green hydrogen by providing a subsidy for the production of green hydrogen (US$3/kg) and blue hydrogen (at least US$0.6/kg, depending on carbon capture efficiency).

Current overall US production of hydrogen amounts to ~10 million tons per annum (MTPA) of which only 5% (0.5 MTPA) constitutes green and blue hydrogen (DOE, 2022). However, for the next decades the *National Clean Hydrogen Strategy and Roadmap* sets a target for clean hydrogen production of 10 MTPA by 2030 and 20 MTPA by 2040. The roadmap adopts a clean hydrogen production standard of less than 4kg of carbon dioxide-equivalent (CO_2e) per kg of H_2, which is in line with the clean hydrogen standard from the IRA.

For our projected cost-estimates, we take the current 2022 production of 0.5 MTPA as a basis and assume a linear growth of green and blue hydrogen until 2032. In order to reach its self-imposed targets for hydrogen production, the US would therefore need to produce 10 billion kilos of clean hydrogen per annum by 2030 and 20 billion kilos of clean hydrogen per annum by 2040. Assuming a green hydrogen share of 50%, which is subsidized at $3 per kilo (with the remaining

__TABLE 2__ Cost-estimates conditional on target

% OF TARGET REACHED	TOTAL COSTS UNTIL 2032
30%	47,0 bn
40%	61,2 bn
50%	75,4 bn
60%	89,6 bn
70%	103,7 bn
80%	117,9 bn
90%	132,1 bn
100%	146,3 bn

blue hydrogen qualifying for US$1.5 of the subsidy), we calculate a total cost of US$146.3 billion until 2032 (Figure 1).

This is almost 10 times the amount officially estimated by the Congressional Budget Office but also considerably higher than other private sector estimates that assume a hydrogen production target of only 6.5 MTPA by 2030 (CBO, 2022; Credit Suisse, 2022).

In order to put our estimates into perspective, Table 1 illustrates our projected costs depending on how close the US is to meeting its hydrogen production targets. It reveals that even in the scenario where the US reaches only one third of its self-imposed targets, the total subsidy costs would still be triple the amount estimated by the CBO.

Our estimates so far only take account of subsidy costs until 2032 and do not include the costs incurred after 2032 (because as long as construction begins before 2032, the tax credit can be claimed for the first 10 years in service). The total cost of paying for 10 million tons of hydrogen for 10 years would be 300 billion USD. This suggests that our estimates are rather at the lower bound of the overall subsidy costs.

ADDITIONAL INFORMATION

Green hydrogen is produced entirely by renewable electricity (e.g. solar or wind power) which powers an electrolyzer that splits water into hydrogen and oxygen. Pink hydrogen is produced using nuclear power instead of renewable power to electrolyze water.
Blue hydrogen is produced using steam to separate hydrogen from natural gas, causing significant carbon emissions, which are captured and sequestered. Sometimes referred to as "turquoise" (i.e. having both blue and green elements).
Grey hydrogen is produced just like blue hydrogen, except carbon emissions are not captured and sequestered, but instead are released into the atmosphere
Brown (made from brown coal) and **black hydrogen** (made from black coal) are produced via gasification, releasing the carbon dioxide into the atmosphere (if the carbon dioxide is captured and sequestered: blue hydrogen).
Source: National Grid (2023)

PRODUCTION TARGET

- U.S. Department of Energy (DOE, 2022)
  Current overall US hydrogen production of ~10 million tons per annum (MTPA). 95% of this production is grey hydrogen and only 5% is clean hydrogen (mainly green and blue), i.e. ~0.5 MTPA.

- **U.S. Department of Energy (DOE, 2022)**
  - 50 MTPA by 2050, with interim targets of 10 MTPA by 2030 and 20 MTPA by 2040
  - Interestingly, the report adopts a clean hydrogen production standard of less than 2kg of carbon dioxide-equivalent (CO_2e) per kg of H_2. In a separate document, the DOE adjusts this figure to 4kg of CO_2e per kg of H_2 to be consistent with the IRA.[28]

- **Credit Suisse (2022):** 6.5 MPTA of clean hydrogen production (i.e. green, pink, blue) by 2030 of which 50% is green hydrogen

PRODUCTION COSTS

- **Credit Suisse (2022):** current cost of green hydrogen in the US of US$2.82/kg (compared to US$4.21–US$4.73/kg in Europe)

- DOE introduced so-called **Hydrogen Shot (2021):**
  - a *1-1-1* goal to cut the cost of clean hydrogen to **$1** per **1** kilogram in **1** decade, which is an 80% reduction from the cost in 2020.
  - Interim goal of $2/kg by 2026.

- Big obstacle to widespread adoption of green (and blue) hydrogen in the U.S. is the carbon hydrogen infrastructure

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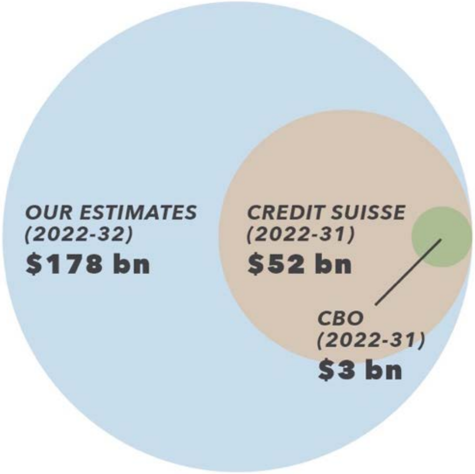
[28] https://www.hydrogen.energy.gov/pdfs/clean-hydrogen-production-standard.pdf

Annex A.4: CCS — Overview

IRA CODE: 13104
TAX CODE: 45Q
PERIOD: 2023–2032 (**but** for first 12 years in service, so payments can last until 2044)

FIGURE 10 *Cost-estimates for CCS Tax Credit*

(sequestering 2% of CO_2 emissions from energy)



Source: CBO, Treeprint Report (Credit Suisse)

TABLE 3 *Cost-estimates conditional on sequestration target*

% OF CO_2 EMISSIONS SEQUESTERED	TOTAL COSTS UNTIL 2032
0.5%	45 bn
1%	90 bn
1.5%	134 bn
2%	178 bn

The tax credit for carbon capture, utilization and storage (CCUS) is meant to make CO_2 sequestration a viable solution for a larger number of industries in the US. It is available for facilities being placed in service from 2023 to 2032 but since it can be claimed for 12 years the tax credit will extend until 2044 in practice. The IRA CCUS credit replaces the old tax credit for carbon capture and lowers the eligibility threshold for sequestration facilities. Furthermore, it increases the tax credit amount to US$85 per ton captured from industrial processes. For direct air capture facilities, it increases the amount to US$130 per ton if utilized and US$180 per ton if stored. For our projected cost-estimates we assume an equal share of facilities applying for the US$85, US$130 and US$180 tax credit, respectively. Drawing upon our projections for the reduction of US emissions, we take Scenario 1 as the baseline, where the US will not meet its emissions targets until 2040 (for further details regarding the emission reduction scenarios see our Renewable Energy Overview). Depending on the percentage of CO_2 sequestered this would amount to **total subsidy costs** of up to **US$178 bn until 2032**, as illustrated in Table 1.
Overall, our estimates considerably exceed the budget currently allocated by the Congressional Budget Office (Figure 1). Private sector estimates vary with some reports forecasting that the costs for the CCUS credit could total US$52 bn (Credit Suisse) while other reports project costs of over US$100 bn between 2023 and the early 2030s (BloombergNEF).
However, our estimates only account for subsidy costs until 2032 and do not include the costs incurred after 2032 (because as long as construction begins before 2032, the tax credit can be claimed for the first 12 years in service). The total cost of providing the subsidy for eligible firms until 2044 would far exceed US$450 bn. This suggests that our estimates are at the lower bound of the overall subsidy costs.

Annex B: Bare Bones Model of demand for EU exports to US

Here we present a simple model of the impact of the IRA on the export opportunities for European producers emphasizing the two key elements, market size and the tariff equivalent of local content rules (e.g. for cars, renewables' components), which allows us to determine under which circumstances one fully or partially offsets the other.

The starting point is the demand for European exports to the US (X) determined by the size of the market (K) and the price:

$$X = Kp^{-\varepsilon}$$

Where epsilon indicates the price elasticity of demand with $\varepsilon > 0$

The size of the market before the IRA is indicated by subscript 0, K_0, resulting in European exports of X_0 equal to:

$$X_0 = K_0 p^{-\varepsilon}$$

The IRA changes two elements:

The size of the market increases from K_0 to K_{IRA} and the price at which European suppliers can compete increases by the tariff equivalent of the local content requirements, denoted by t.

It follows that post IRA European exports are given by:

$$X_{IRA} = K_{IRA}[p(1+t)]^{-\varepsilon}$$

The last two equations can be used to determine whether and under what conditions EU exports to the US increase. The ratio of post IRA to pre-IRA exports is given by:

$$\frac{X_{IRA}}{X_0} = \frac{K_{IRA}[p(1+t)]^{-\varepsilon}}{K_0 p^{-\varepsilon}}$$

$$\frac{X_{IRA}}{X_0} = \frac{K_{IRA}(1+t)^{-\varepsilon}}{K_0} = \frac{K_{IRA}}{K_0(1+t)^{\varepsilon}}$$

This can be rewritten in natural logarithmic terms as:

$$ln\left(\frac{X_{IRA}}{X_0}\right) = ln\left(\frac{K_{IRA}}{K_0}\right) - \varepsilon t$$

Which uses the approximation that ln(1+t) is approximately equal to t for small values of t. This equation has one simple implication: if the elasticity of demand is equal to 1, the percentage increase in the market size needs only to be larger than the tariff equivalent or price handicap.

The point at which EU industry would just be indifferent would be given by the conditions that:

$$proportional\ increase\ in\ exports = proportional\ increase\ in\ market - \varepsilon t$$

More generally, it follows that post-IRA exports (from the EU to the US) will be higher than before if the proportional increase in market size is larger than the tariff equivalent of the Buy American provisions multiplied by the elasticity of demand.

Looking first at **EVs**, Table 4 presents a meta-analysis of available own-price elasticities for EVs, including hybrid and fully electric.[29] It can be seen that there is variation in estimated elasticities, which come from different types of data, countries, time periods and empirical approaches. The elasticities range between 0.82 and 8.2, with a median value of 1.72 and an average of 2.44.[30]

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[29] The own-price elasticity is the relevant elasticity in our context, since we have discussed how clean-dirty vehicle substitution, as well as within-EV market substitution between normal and premium vehicles are likely to have only a limited impact.

[30] Two important differences between Beresteanu and Li (2021) and the other studies are: i) instead of fully electric vehicles they consider hybrid cars, and ii) the sample period refers to earlier years.

TABLE 4 Meta-analysis of estimate own-price elasticities for EVs.

Authors & publication date	Journal	Country & sample years	Estimated Elasticity
Muehlegger & Rapson (2022)	*Journal of Public Economics*	United States, 2014/2018	*2.1*
Springel (2021)	*American Economic Journal: Economic Policy*	Norway, 2015/2015	*1.5 - 2.04*
Fridstrøm & Østli (2021)	*European Transport Research Review*	Norway, 2002/2016	*1.27 - 1.72*
Xing, Leard & Li (2021)	*Journal of Environmental Economics and Management*	United States, 2010/2014	*2.76*
Beresteanu & Li (2021)	*International Economic Review*	United States, 1999/2006	*8.40*
Li, Tong, Xing & Zhou (2017)	*Journal Association of Environmental and Resource Economists*	United States, 2011/2013	*0.82 - 1.38*
Glerum, Stankovikj, Thémans & Bierlaire (2014)	*Transportation Science*	Switzerland, 2011	*0.92*

Table 5 presents a matrix with the corresponding values for different assumptions about tariff equivalent and demand elasticity.[31] It can be seen that even for extreme values of tariff equivalents and elasticities, the increase in market size necessary to offset the impact of LCRs is in the range of the manifold increases in market size that can be expected from the IRA. Estimated demand elasticities for energy-intensive industries such as steel and cement are generally lower than 1, see for instance Karlson (1983) which calculates an elasticity of 0.303, or Demainlly and Quirion (2008) that calculate 0.62. Therefore, the simulated values in Table 5 should be considered as

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[31] The simulated value is obtained by setting $\ln(X_{IRA}/X_0) = 0$.

upper bounds for the required increase in market size necessary to offset the effect of LCRs.

TABLE 5 Required % change in market size necessary to offset LCRs

		Own-price demand elasticity		
		0.82	**1.72**	**8.4**
Tariff equivalent	**5%**	4%	9%	42%
	10%	8%	17%	84%
	15%	12%	26%	126%

Looking at the case of **renewables,** the tariff equivalent was lower. For the PTC it was around 10%, but also for the ITC it was in the order of 17%, with possibly some partial adjustment as the required local content increases. Even at the end of the transition period for the local content rules (i.e. after 2030) the tariff handicap of European producers would be less than 10% (PTC) and 17% (ITC). The elasticity of demand for renewables components should be higher than for EVs because in this business-to-business market there is little brand loyalty.

Moreover, there are other sectors for which the market for EU products will expand: e.g. machinery for hydrogen production. There are no local content requirements in these sectors, which thus represent a pure market opportunity for green machinery.

Table 6 presents different values for the projected expansion in market size in 2030 due to the IRA, separately for EVs and renewables. In the first row, we use as a criterion the Biden target, which we assume will be reached. For EVs, the 50% sales of EVs target corresponds to selling 7 million vehicles. As 1 million EVs were sold in 2023 (7.2% share), this corresponds to a 600% increase in the market. For renewables, the average installed capacity per year between 2012 and 2021 is roughly 20 GW (Global EV Outlook, 2022).

We estimate that the needed installed capacity of solar and wind renewables is (245.6+563.4) 809 GW. If the target is reached by 2032, this corresponds to additional 89 GW per year, which is a 345% increase. Both these estimates of market expansion are much higher than those required to leave EU exporters unaffected by the IRA (Table 5).

In the second line of Table 6, we use the projections of Bistline, Mehrotra, & Wolfram (2023). Their model predicts that in 2030, the share of EV sales will be 44%. This implies roughly 6 million EVs sold, which is a 500% increase in market size. For renewables, their model predicts average annual additional 40 GW, namely a 100% increase relative to the 20 GW over the period 2012-2021. Also in this case, the expansion in demand would be sufficient to leave EU exporters unaffected in all but the most pessimistic scenario in Table 5.

Finally, we use the most conservative publicly available projections, from Larsen et al. (2022). They estimate that in 2030, the share of EV sales will be roughly 20%, which corresponds to 2.7 million EVs. This implies a growth in the EV market of 170%. For renewables, Larsen et al. (2022) estimate that the annual average additional capacity from renewables is 34 GW, which corresponds to a 70% increase in market size. This is lower than the critical values in Table 5 in the two worst scenarios.

TABLE 6 Projected % change in market size due to IRA

		EVs	**Renewables (solar+wind)**
	Biden Target	600%	345%
	Brookings (2023)	500%	100%
	Larsen, et al. (2022)	170%	70%

Annex C: EU Green Energy Subsidies

Overall, the data on renewable energy subsidies (RES) for the period from 2015 until 2020 comprises **454 individual subsidies from the EU members states (EU27)** (European Commission, 2022). Looking at the aggregate level, the **total amount** of RES has been steadily increasing to **€80,1 billion** in **2020** (up from €70,2 billion in 2015). However, there is substantial heterogeneity across EU members states with Germany alone contributing more than 40% to the total amount of green energy subsidies (Figure 1).

***FIGURE 11** EU27 RES by member states (2020)*

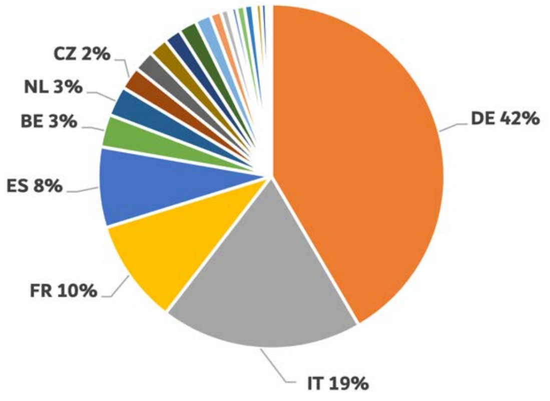
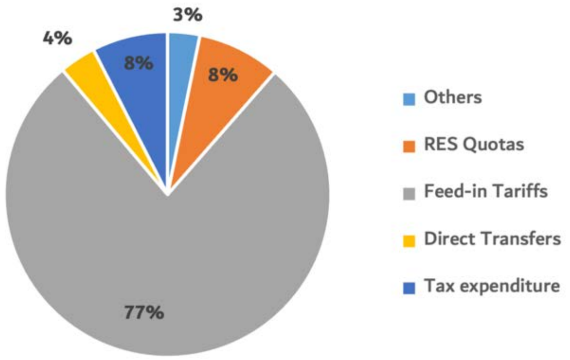
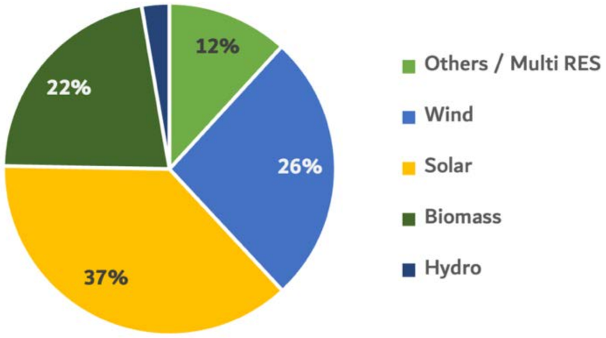


***FIGURE 12** EU27 RES by financial instruments (2020)*



With respect of the **financial instruments** of the RES, the EU27 do not differ much in their strategy. In contrast to the Inflation Reduction Act (IRA) in the US, the vast majority of the EU subsidies are being provided through feed-in tariffs and feed-in premiums (Figure 2). A significantly lower proportion is distributed through tax expenditures (for example, tax reduction, tax exemptions, tax refunds, tax credits and tax allowances) or RES quotas with tradable certificates.[32] Among the biggest EU economies the only exception is Italy that follows a somewhat more diversified strategy regarding financial instruments. This is illustrated by Figure 3, which depicts the trajectory of RES from 2015–2020 in the four biggest EU economies, disaggregated by financial instruments. While the total volume of subsidies increased for Germany and France, it stagnated for Italy and Spain (note, however, the different scale of the y-axis). Also, in most countries the composition of financial instruments has slightly changed with tax expenditure instruments becoming increasingly more important in recent years.

***FIGURE 13** EU27 RES by industry (2020)*



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[32] As for the other two categories: (1) *Direct Transfers* includes government grants and soft loans and (2) *Others* includes producer price guarantees (regulations), capacity payments and differentiated grit connection charges.

Looking at the **targeted industries** of European RES, Figure 4 illustrates how solar energy technology (€30 billion) receives the highest share of subsidies of all renewables in 2020 followed by wind (€21 billion) and biomass (€18 billion). Although the overall composition did not change significantly from 2015 to 2020, subsidies for the wind sector in particular increased over this period and are mainly responsible for the overall increase in EU renewable energy subsidies (Figure 5). Governmental support for other sectors like solar, biomass or hydro have not expanded in a similar fashion. Unsurprisingly, there is large variation in the targeted industries, as EU member states seek to support technologies with higher local potential. For example, countries with high solar irradiation like Cyprus, Greece, Italy, Malta, Spain mainly targeted the solar industry.

FIGURE 14 *Subsidies by industry*

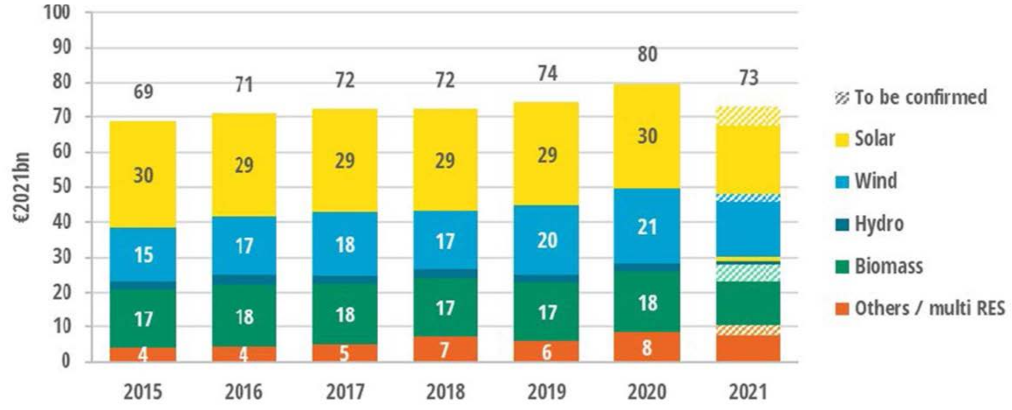

FIGURE 15 *Subsidies by industry and member state*