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Influence of market structures and market regulation on the carbon market

Case Study Report

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Influence of market structures and market regulation on the carbon market

Case study report

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Abstract

This report analyses the influence of the Cap and Trade (CaT) system and the electricity market in California along two main questions: How do CaT design features affect the environmental effectiveness of the system and the quality of the carbon price signal? How do electricity market design features affect the carbon price induced abatement in the power sector? Based on publicly available data and expert interviews, we derive four main findings on the impact of the electricity market structure on the quality of the California Carbon Allowances (CCA) price.

First, the capacity mix impacts the role of the CCA price for the electricity sector. Due to the large share of gas capacities and the very small share of coal plants, carbon reduction in the electricity sector can only be achieved by decreasing output or investing in carbon-free technologies. Second, complementary policies affect the marginal abatement cost (MAC) in the electricity sector and indirectly also the carbon price. Thus, the CCA price only reflects the MAC conditional on all the complementary policies. Third, the redistribution of large shares of the carbon revenue to consumers, as so-called California Climate Credits, increases the political acceptance of the system. Finally, the CaT system should currently not be seen as the major climate policy instrument in the Californian electricity sector. The broad mix of other policies buffer the carbon price and make the total costs for the transformation less transparent. Yet, this might change in the future when reduction targets become more stringent.

This case study is part of the project "*Influence of market structures and market regulation on the carbon market*" that aims to investigate the interdependencies between carbon and energy markets in Europe, California, China, South Korea, and Mexico.

Kurzbeschreibung

Dieser Bericht analysiert die Interaktion des Emissionshandelssystems (Cap and Trade, CaT) und des Strommarktes in Kalifornien entlang zweier Hauptfragen: Wie wirken sich die Gestaltungsmerkmale des CaT auf die ökologische Wirksamkeit des Systems und die Qualität des CO_2-Preissignals aus? Wie wirken sich die Gestaltungsmerkmale des Strommarktes auf die durch das CO_2-Preissignal induzierte Emissionsreduktion im Stromsektor aus? Basierend auf öffentlich verfügbaren Daten und Experteninterviews, ziehen wir vier wichtige Schlussfolgerungen zu den Auswirkungen der Strommarktstruktur auf die Qualität des CO_2-Preises.

Erstens beeinflusst der Kapazitätsmix die Rolle des CO_2-Preises für den Stromsektor. Aufgrund des großen Anteils der Gaskapazitäten und des sehr geringen Anteils der Kohlekraftwerke kann die Emissionsreduktion im Stromsektor nur durch eine Verringerung der Produktion oder durch Investitionen in emissionsneutrale Technologien erreicht werden. Zweitens beeinflussen zahlreiche begleitende Politiken die Grenzvermeidungskosten im Elektrizitätssektor und indirekt auch den CO_2-Preis. Somit spiegelt der CO_2-Preis nur die Grenzvermeidungskosten unter Berücksichtigung der zusätzlichen Politiken wider. Drittens wird die Akzeptanz des Systems erhöht durch die sogenannten Kalifornischen Klimakredite, welche einen Großteil der CO_2-Einnahmen an die Konsument*innen zurückerstatten. Viertens sollte das Emissionshandelssystem derzeit nicht als das wichtigste Klimapolitikinstrument im kalifornischen Stromsektor angesehen werden. Der breite Mix aus anderen Politiken führt zu einem tendenziell niedrigen CO_2-Preis und macht die Gesamtkosten für die Transformation weniger transparent. Das könnte sich jedoch in Zukunft ändern, wenn die Emissionsreduktionsziele ambitionierter werden.

Diese Fallstudie ist Teil des Projekts "Influence of market structures and market regulation on the carbon market", welches zum Ziel hat, die Auswirkungen der Marktstrukturen und Regulierungen auf CO_2-Märkte zu identifizieren und die Abhängigkeiten von CO2- und Energiemärkten in Europa, Kalifornien, China, Südkorea und Mexiko zu untersuchen.

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APCR	Allowance Price Containment Reserve
CAISO	Californian Independent Transmission System Operator
CARB	California Air Resources Board
CaT	Cap and Trade
CCA	Californian Carbon Allowances
CHP	Combined Heat and Power
CO_{2eq}	Carbon dioxide equivalent
CPUC	California Public Utilities Commission
EPS	Emissions Performance Standard
EU ETS	European Emission Trading System
GHG	Greenhouse gas
ICE	Intercontinental Exchange
IOUs	Investor-Owned electrical distribution Utilities
IRP	Integrated Resource Planning
MAC	Marginal Abatement Cost
PG&E	Pacific Gas and Electric company
POUs	Publicly Owned electrical distribution Utilities
RGGI	Regional Greenhouse Gas Initiative
RPS	Renewable Portfolio Standard
TWh	Terawatt hours (measuring units for energy)
WCI	Western Climate Initiative

Summary and conclusions

This report analyses the interaction of California's Cap and Trade (CaT) system and the electricity market along two main questions:

- How do CaT design features affect the environmental effectiveness of the system and the quality of the carbon price signal?
- How do electricity market design features and regulation affect the carbon price induced abatement in the power sector?

In the following, we first summarize our most important findings and then draw some interim conclusion on the interaction of the two markets.

Impacts of carbon market design on the quality of the carbon price signal

The environmental effectiveness and the quality of the allowance price signal are most affected by the emission target, the possibility of using offsets, and the price corridor:

- **Volatility:** Volatile carbon prices are an indicator that a market is able to react to newly revealed information. Yet, excessive volatility makes it difficult for market participants to make abatement and trading decisions. Short-term volatility of the price of Californian carbon allowances (CCA) is near zero in nearly all phases of the program. The major reason seems to be the binding price floor, essentially setting the CCA price at the minimum price level. Another reason might be that due to the consignment of primary allocation (i.e., investor-owned utilities (IOUs) are required to consign all freely allocated allowances to auction), the quarterly auctioned amount of allowances sums up to two third of total allowances. Consequently, there is little trade on secondary markets as the primary allocation is close to the efficient allocation. According to Borenstein et al. (2019) prices tend to be extremely low (near the floor) or extremely high (near the price ceiling) due to the impact of complementing policies and lack of scalable cost-effective short-term abatement options. Additional supply sources such as offset credits and linking to the Québec trading system do not seem to influence volatility.
- **Reflection of MAC:** In the past, the price for Californian allowances seemed to be mostly determined by the level and development of the auction reserve price. Experts agree that the market clearing price was "artificially" kept low by the implementation of many mandated policy programs. These complementary policies significantly reduce emissions of covered entities and thus are decreasing the demand and the carbon price (Borenstein et al. 2019).
- **Predictability:** Because investors have a planning horizon of several years, the long-term predictability of the price signal is essential to foster low carbon investments. The price corridor presumably has the largest impact on predictability: By decreasing the range of possible price realizations, the price corridor leads to a strong increase in the predictability of the CCA price. CaT's target for 2030 is clearly regulated to be 40% below 1990. So far, carbon neutrality for 2045 is announced but still not put to law, leaving a degree of regulatory uncertainty making it more difficult to forecast price developments after 2030. The usage of offsets and the linking to Québec make it more difficult to forecast prices as more influences have to be taken into account. Due to the smaller size of the Québec system, this impact can be expected to be small.

- **Environmental effectiveness:** The environmental effectiveness equals the amount of emissions abated. It is thus mainly affected by design elements that change the emissions cap. The usage of offsets decreases the (domestic) effectiveness of the CaT, also linking with the Québec system is very likely to have impacted environmental effectiveness, but to an unknown, probably small extent. The direction depends on whether California is a net importer or exporter of emissions, and thus varies over the years. In its current form, the price corridor does not alter the environmental effectiveness of the system, as unsold allowances are set aside but not cancelled out of the system. If the hard price ceiling becomes effective in the future, this could weaken the environmental effectiveness of the system.

Impact of electricity market structure on the abatement induced by carbon prices

The electricity sector abatement induced by the carbon price depends on market structure and regulations and is rather limited in California for the following reasons:

- **Capacity mix:** The existing capacity mix impacts the role of carbon prices for the dispatching of power plants as well as for investment decisions. California's rather monolithic conventional capacity mix relying nearly entirely on gas generation implies a near-zero short-term abatement potential in the form of coal-to-gas fuel switching. Thus, the impact of the carbon price on dispatch decisions is rather small.
- **Complementary policies:** Other policies play a key role determining the importance of carbon prices for dispatch and investment decisions. Nearly all complementary policies decrease the role of carbon prices for the electricity sector. Supply side programs giving support on production basis (renewable and CHP support) incentivize the generation of certain technologies, and thus investment into these capacities. As a consequence, the role of carbon prices for dispatch and investment decisions is reduced. Likewise, technology mandates (emission performance standards and phase-out of once through cooling) direct investments and divestures towards a less carbon intensive capacity mix. This reduces the role of carbon prices for investment decisions. As in the longer-run, the capacity mix becomes less carbon-intense, the role of the CCA price for dispatch is also reduced. On the consumer side, energy efficiency programs stimulate investments into energy saving technologies and, thus, reduce the role of the CCA price for these decisions.
- **California Climate Credits:** Part of the income of freely allocated allowances has to be transferred to final consumers. Currently, this redistribution of rent is implemented in a per-household, i.e., lumpsum, manner, and thus does not affect the role of carbon prices.

Impact of electricity market structure on the quality of the carbon price signal

Provided by our observations on the CaT and the electricity market structure, we can derive the following conclusions regarding the impact of the electricity market structure on the quality of the CCA price.

First, the capacity mix is unlikely to influence the quality of the carbon price signal. It does, however, impact the role of the CCA price for the electricity sector. Due to the large share of gas capacities and the very tiny share of coal plants, carbon reduction in the electricity sector can only be achieved by decreasing output or investing in carbon-free technologies.

Investments are subject to monitoring through the Integrated Resource Planning (IRP) process taking place every two years. We observe a strong system of complementary policies designed to steer the electricity system to fulfill California's climate targets. These additional policies affect the MAC in the electricity sector and indirectly also the CCA price. Thus, the CCA price only reflects the conditional MAC, i.e., the MAC conditional on all the complementary policies.

As shown by Borenstein et al. (2019), the large usage of complementary policies implies that most of the cheap abatement options are incentivized by these policies leading to a very steep MAC curve. Together with the imposed CCA price corridor, this leads to a high probability of the CCA price either being at the price floor or ceiling.

Overall, the CaT system should currently not be seen as the major climate regulation in the Californian electricity sector. Or, as one of our interview partners stated: "Carbon pricing is the complementary policy." The broad mix of other policies buffer the carbon price and make the total costs for the transformation less transparent. It seems that the role of the CaT is to ultimately cap emissions and provide a safety net in case other, more targeted policies do not deliver on emission reductions. In doing so, it also provides a broad allowance price across most sectors and increases the acceptance of climate policy further by generating revenue which is partly redistributed back as California Climate Credits and partly used to finance energy efficiency programs. Nevertheless, most of our interview partners also expressed the expectation that due to the increasing stringency, it is likely that carbon pricing might become a driver of the transformation to a low carbon economy in the future.

Zusammenfassung und Schlussfolgerungen

Dieser Bericht analysiert das Zusammenspiel des kalifornischen Cap-and-Trade-Systems (CaT) und des Strommarktes entlang zweier Hauptfragen:

- Wie wirken sich CaT-Designmerkmale auf die Umweltwirksamkeit des Systems und die Qualität des CO_2-Preissignals aus?
- Wie wirken sich die Gestaltungsmerkmale und die Regulierung des Strommarktes auf die durch den CO_2-Preis induzierte Verringerung des Kohlenstoffausstoßes im Stromsektor aus?

Im Folgenden fassen wir unsere wichtigsten Ergebnisse zusammen.

Auswirkungen der Ausgestaltung des CO_2-Marktes auf die Qualität des CO_2-Preissignals

Die Umweltwirksamkeit und die Qualität des Preissignals für Zertifikate werden am stärksten durch das Emissionsziel, die Möglichkeit der Nutzung von Offsets und den Preiskorridor beeinflusst:

- **Volatilität:** Volatile CO_2-Preise sind ein Indikator dafür, dass ein Markt in der Lage ist, auf neue Informationen zu reagieren. Eine übermäßige Volatilität macht es den Marktteilnehmern jedoch schwer, Entscheidungen zu treffen. Die kurzfristige Volatilität des Preises für kalifornische CO_2-Zertifikate (CCA) ist in fast allen Phasen des Programms nahe Null. Der Hauptgrund scheint die verbindliche Preisuntergrenze zu sein, die den CCA-Preis im Wesentlichen auf das Mindestpreisniveau festlegt. Ein weiterer Grund könnte darin liegen, dass aufgrund des „Consignment“ der Erstzuteilung der Zertifikate (d.h. Energieversorgungsunternehmen im Besitz von Investoren müssen ihre kostenlos zugeteilten Zertifikate an den Auktionen anbieten) die vierteljährlich versteigerte Menge der Zertifikate zwei Drittel der gesamten Zertifikate ausmacht. Folglich gibt es wenig Handel auf den Sekundärmärkten, da die Erstzuteilung der Zertifikate nahe an der effizienten Zuteilung liegt. Gemäß Borenstein et al. (2019) tendieren die Preise dazu, extrem niedrig (in der Nähe der Untergrenze) oder extrem hoch (in der Nähe der Preisobergrenze) zu sein, was auf den Effekt zusätzlicher Politikmaßnahmen sowie den Mangel an skalierbaren, kosteneffizienten und kurzfristigen Emissionsvermeidungsoptionen zurückzuführen ist. Zusätzliche Quellen wie internationale Offsets und die Anbindung an das Handelssystem von Québec scheinen die Volatilität nicht zu beeinflussen.
- **Widerspiegelung der Grenzvermeidungskosten:** In der Vergangenheit schien der Preis für kalifornische Zertifikate hauptsächlich durch die Höhe und Entwicklung des Auktionsreservepreises bestimmt zu werden. Expert*innen sind sich einig, dass der Preis durch diverse politische Programme "künstlich" niedrig gehalten wurde. Diese zusätzlichen Politikmaßnahmen reduzieren die Emissionen und senken somit die Nachfrage und den CO_2-Preis (Borenstein et al. 2019).
- **Vorhersagbarkeit:** Da Investoren einen Planungshorizont von mehreren Jahren haben, ist die langfristige Vorhersagbarkeit des Preissignals für die Förderung emissionsarmer Investitionen von entscheidender Bedeutung. Der Preiskorridor hat vermutlich den größten Einfluss auf die Vorhersagbarkeit: Indem er die Bandbreite möglicher Preise verringert, verbessert er die Vorhersagbarkeit des CCA-Preises. Das CaT-Ziel für 2030 ist klar geregelt

und liegt 40% unter dem von 1990. Bisher ist die Klimaneutralität für 2045 zwar angekündigt, aber noch nicht gesetzlich verankert, so dass ein gewisses Maß an regulatorischer Unsicherheit verbleibt, was eine Prognose der Preisentwicklung nach 2030 erschwert. Die Nutzung von Offsets und die Anbindung an Québec erschweren die Preisprognose, da zusätzliche Faktoren berücksichtigt werden müssen. Aufgrund der geringeren Größe des Systems in Québec ist davon auszugehen, dass dieser Einfluss gering sein wird.

- **Umweltwirksamkeit:** Die Umweltwirksamkeit entspricht der Menge der vermiedenen Emissionen. Sie wird hauptsächlich durch Designelemente beeinflusst, die die Emissionsobergrenze verändern. Die Verwendung von Offsets vermindert die (inländische) Wirksamkeit des CaT. Auch die Verknüpfung mit dem Emissionshandelssystem in Québec dürfte die Umweltwirksamkeit sehr wahrscheinlich beeinflusst haben, jedoch in unbekanntem, wahrscheinlich geringem Maße. Die Richtung hängt davon ab, ob Kalifornien ein Nettoimporteur oder -exporteur von Emissionen war, und variiert daher im Laufe der Jahre. In seiner gegenwärtigen Form verändert der Preiskorridor die Umweltwirksamkeit des Systems nicht, da unverkaufte Zertifikate zurückgestellt, aber nicht aus dem System gelöscht werden. Wenn künftig die harte Preisobergrenze wirksam werden sollte, könnte dies die Wirksamkeit des Systems schwächen.

Auswirkungen der Struktur des Strommarktes auf die durch die CO_2-Preise induzierte Emissionsvermeidung

Die durch den CO_2-Preis induzierte Emissionsreduktion im Stromsektor hängt von der Marktstruktur und anderen Regulierungen ab. Sie ist in Kalifornien aus folgenden Gründen eher begrenzt:

- **Kapazitätsmix:** Der bestehende Kapazitätsmix wirkt sich auf die Rolle der CO_2-Preise sowohl für den Dispatch von Kraftwerken als auch für Investitionsentscheidungen aus. Der eher monolithische konventionelle Kapazitätsmix Kaliforniens, der sich fast ausschließlich auf die Gaserzeugung stützt, impliziert ein kurzfristiges Vermeidungspotenzial (in Form einer Umstellung von Kohle- auf Gasstromproduktion) von nahezu Null. Daher ist der Einfluss des CO_2-Preises auf Dispatch-Entscheidungen gering.

- **Zusätzliche Politiken:** Zusätzliche energiepolitische Maßnahmen spielen eine Schlüsselrolle für den Einfluss der CO_2-Preise auf Dispatch- und Investitionsentscheidungen. Fast alle zusätzlichen Politiken verringern die Rolle der CO_2-Preise für den Stromsektor. Programme auf der Angebotsseite wie die Subventionierung der Produktion (Förderung von erneuerbaren Energien und Kraft-Wärme-Kopplung) bieten Anreize für die Erzeugung bestimmter Technologien und damit für Investitionen in diese Kapazitäten. Infolgedessen wird die Rolle der CO_2-Preise für Dispatch- und Investitionsentscheidungen verringert. Ebenso lenken Technologiestandards Investitionen und Veräußerungen in Richtung eines weniger emissionsärmeren Kapazitätsmix. Dadurch wird die Rolle der CO2-Preise für Investitionsentscheidungen verringert. Da der Kapazitätsmix langfristig emissionsärmer wird, verringert sich auch die Rolle des CCA-Preises für den Dispatch. Auf der Verbraucherseite stimulieren Energieeffizienzprogramme Investitionen in energiesparende Technologien und verringern damit die Rolle des CCA-Preises.

- **Kalifornische Klimakredite:** Ein Teil des Einkommens der kostenlos zugeteilten Zertifikate muss an die Endverbraucher rückerstattet werden. Gegenwärtig wird diese Umverteilung der Rente pro Haushalt, d.h. pauschal, durchgeführt und beeinflusst daher die Rolle der CO_2-Preise nicht.

Auswirkungen der Struktur des Strommarktes auf die Qualität des CO_2-Preissignals

Aus unseren Beobachtungen des Emissionshandelssystems und des Strommarktdesigns können wir folgende Schlussfolgerungen zu den Auswirkungen der Struktur des Strommarktes auf die Qualität des CO_2-Preises ableiten.

Erstens ist es unwahrscheinlich, dass der Kapazitätsmix die Qualität des CO_2-Preissignals beeinflusst. Er hat jedoch Einfluss auf die Rolle des CCA-Preises für den Stromsektor. Aufgrund des großen Anteils der Gaskapazitäten und des sehr geringen Anteils der Kohlekraftwerke kann die Emissionsreduktion im Stromsektor nur durch eine Verringerung der Stromproduktion oder durch Investitionen in emissionsneutrale Technologien erreicht werden.

Die Investitionen unterliegen der Überwachung durch den alle zwei Jahre stattfindenden Prozess der Integrierten Ressourcenplanung (IRP). Wir beobachten zahlreiche begleitende Politiken, die darauf abzielen, dass Kalifornien seine Klimaziele erreicht. Diese zusätzlichen Politiken wirken sich auf die Grenzvermeidungskosten im Elektrizitätssektor und indirekt auch auf den CO_2-Preis aus. Somit spiegelt der CO_2-Preis nur die Grenzvermeidungskosten unter Berücksichtigung der zusätzlichen Politiken wider.

Wie Borenstein et al. (2019) zeigen, führen die zusätzlichen Politikmaßnahmen dazu, dass die meisten der billigen Vermeidungsoptionen durch diese Maßnahmen angereizt werden, was zu einer steilen Grenzvermeidungskostenkurve für die verbleibenden Emissionen führt. Zusammen mit dem auferlegten Preiskorridor führt dies zu einer hohen Wahrscheinlichkeit, dass der CO_2-Preis entweder an der Preisunter- oder -obergrenze liegt.

Insgesamt sollte das Emissionshandelssystem derzeit nicht als das wichtigste klimapolitische Instrument im kalifornischen Stromsektor angesehen werden. Oder, wie einer unserer Interviewpartner sagte: "Das Emissionshandelssystem ist die ergänzende Politikmaßnahme". Der breite Mix aus anderen Politiken führt zu einem tendenziell niedrigen CO_2-Preis und macht die Gesamtkosten für die Transformation weniger transparent. Die Rolle des Emissionshandels scheint letztlich darin zu bestehen, ein Sicherheitsnetz für den Fall zu schaffen, dass andere, gezieltere Politiken nicht zu genügend Emissionsreduktionen führen. Außerdem gibt es aufgrund des Emissionshandels einen Zertifikatspreis in den meisten Sektoren und die Akzeptanz der Klimapolitik wird erhöht, weil Einnahmen als kalifornische Klimagutschriften zurückverteilt und zur Finanzierung von Energieeffizienzprogrammen verwendet werden. Nichtsdestotrotz äußerten die meisten unserer Interviewpartner auch die Erwartung, dass es aufgrund der Verschärfung der Emissionsreduktionsziele wahrscheinlich ist, dass die CO_2-Preisgestaltung in Zukunft zu einer treibenden Kraft bei der Transformation zu einer emissionsarmen Wirtschaft werden könnte.

1 Introduction

The project “Influence of market structures and market regulation on the carbon market” aims to identify the impact of market structures and regulations on carbon markets and to investigate the interdependencies between carbon and energy markets. In a first step, Acworth et al. (2019) identified major interaction channels based on a literature study. In a second step, case studies[1] are used to analyse the mechanisms and interaction channels based on the previously developed framework. In this report, we present the case study for California, including the Cap and Trade (CaT) system and the electricity market. The aim of the case study is to analyse the design of the ETS and electricity market and regulations in order to understand how these affect the carbon price as well as market interactions in terms of emission reduction. The report addresses the following two primary questions:

1. How do the CaT design features affect the environmental effectiveness of the system and the quality of the carbon price signal?
2. How do electricity market design features affect the carbon price induced abatement in the power sector?

The report is structured in two parts. First, we describe the California CaT, its most important design features, and the development of traded allowance volumes and allowance prices. Further, we assess the impact of design features on the effectiveness of the system and the quality of the allowance price along four dimensions[2]:

- Environmental effectiveness: equivalent to the amount of emissions abated.
- Reflection of marginal abatement cost (MAC): Examining the MAC enables to examine whether the price signal is distorted.
- Long-term price predictability: Because investors have a planning horizon of several years, the long-term predictability of the price signal is essential to foster low carbon investments.
- Price volatility: Volatile carbon prices are an indicator that a market is able to react to newly revealed information, e.g., changes in production cost. Yet, excessive volatility makes it difficult for market participants to make abatement and trading decisions.

Second, we describe the electricity market in terms of design, supply, and demand. We then assess the interaction of carbon and electricity markets, focusing on the impact of carbon prices on electricity generation, demand, and consequently abatement. We assess this impact along the three main abatement channels:

- Fuel switch: Short-term abatement through change in dispatch.
- Low carbon investment/divestment: Long-term abatement through investment in low carbon technologies or divestment from fossil technologies.
- Demand reduction: Short to long-run abatement due to demand reduction induced by higher electricity prices for consumers in wholesale and retail markets.

[1] In addition to California, case studies for China, European Union, Korea and Mexico are conducted.
[2] See Acworth et al. (2019) for an overview of these dimensions.

All three abatement channels depend on the pass-through of the carbon price signal to bids in the electricity market, and thus wholesale market prices. We thus also provide evidence on cost pass-through.

As mentioned above the framework of this report is based on Acworth et al. (2019). For the analyses, we (i) use literature on carbon and electricity market regulations, research articles, and secondary literature; (ii) analyse electricity and carbon market data from transmission system operator CAISO as well as the US Energy Information Agency and (iii) conduct semi-structured interviews with different stakeholders from companies, regulators, think thanks and universities in the U.S..

With our analyses we provide descriptive and narrative evidence on the interactions of carbon and electricity market regulations in California. A thorough quantitative assessment of causal relations is beyond the scope of this project. Also, it is important to note that the results from expert interviews provide a range of expert opinions, but cannot be seen as representative.

This report proceeds as follows. Section 2 describes design and regulation of California's CaT, Section 3 assesses their impact on environmental effectiveness and the quality of the price signal, Section 4 introduces the Californian electricity market, Section 5 analyses the impact of electricity market design on carbon price induced abatement in the power sector. The report ends with a summary and conclusions.

2 Design and regulation of the ETS

The California Cap-and-Trade (CaT) Program covers about 80% of the state's greenhouse gas (GHG) emissions from the power and industry sectors as well as transport and heating fuels (ICAP, 2020) and is thus the most comprehensive CaT worldwide (World Bank 2019).[3] All covered entities – those responsible for at least 25,000 tons of carbon dioxide (CO_2) equivalent per year – must surrender one allowance or, within a fixed limit, an approved offset credit for each ton of their verified GHG emissions (CARB, 2019a). Regulated entities must surrender allowances annually equal to 30% of the previous year's verified emissions and allowances for the remaining emissions at the end of every three-year compliance period (ibid).

Launched in 2012, California was the second mandatory carbon market in the U.S. after the Regional Greenhouse Gas Initiative (RGGI) but the first to cover sectors beyond electricity. The CaT program was established through Assembly Bill 32 in 2006, which delegated regulatory authority to the California Air Resources Board (CARB). The passage of Assembly Bill 398 in 2017 extended the program until 2030 and required CARB to implement a regulatory overhaul that included limits to offsets and changes to allocation provisions and the market stability mechanisms (Assembly Bill 398).

California has been a member of the Western Climate Initiative (WCI) since 2007 and the CaT is linked to Québec's cap-and-trade program since January 2014 (CARB, 2015). The two jurisdictions hold joint auctions quarterly. California is unique among ETSs in that it requires some regulated entities (e.g. electrical distribution utilities and natural gas suppliers) to consign at least a portion of their free allocation to auction and stipulates how they use the proceeds (see Section 2.1.2 for more details).

Table 1 gives an overview of supply and demand side design features in the California CaT Program. In the following, we describe the individual design features of the California CaT Program. In chapter 3, we reflect on the design features' impact on the environmental effectiveness of the system and the quality of the allowance price signal along three dimensions: (1) price volatility, (2) reflection of the marginal abatement cost (MAC), and (3) long-term predictability.

[3] The California Air Resources Board (CARB) reports total GHG emissions in 2017 of 424 Mt CO_2eq (CARB, 2019b), from which 363 Mt CO_2eq were covered by the CaT.

Table 1: Overview supply and demand side design features in the CaT Program

Feature	California CaT Design	Comment
Allowance Cap	Absolute	Absolute cap: 334.2 Mt CO_2e (2020) Average annual reduction factor (compared to avg. yearly emissions) - 2015-2017: 3.1% - 2018-2020: 3.4% - 2021-2030: 5%
Mid-term Target **Long-term Target**	2030 target: adopted 2045 target: established by executive order	2030: 40% reduction from 1990 levels 2045 target through Executive Order B-55-18 sets target of GHG neutrality
Primary Allocation (in electricity sector)	Consignment auctions, free allocation, and auctioning	Investor-owned electric utilities required to consign all freely allocated allowances to auction; publicly owned electric utilities and electric cooperatives receive free allocation that they can hold for compliance or consign to auction
Banking **Borrowing**	Allowed Not allowed	Within & across periods but subject to a holding limit Future allowance vintages can be purchased at auction but not used for compliance until their year of validity
Market Stability Mechanism	Price bounds	Minimum price (Auction Reserve Price) that increases every year; Allowance Price Containment Reserve that supplies allowances when prices reach specific points; additional price ceiling starting 2021
Voluntary Cancellation	Allowed	
Coverage	~80% of state GHG emissions (2020)	Mostly CO_2 but also CH_4, N_2O, SF_6, HFCs, PFCs, NF_3, and other fluorinated GHGs.
Market participation	Open system	

2.1 Allowance supply

This section describes the supply side features of California's CaT Program.

2.1.1 Allowance Cap and Long-term Targets

The California CaT Program has an absolute allowance cap aligned to the 2030 reduction target of 40% below 1990 levels. By 2031, the cap will stand at 193.8 Mt CO_2eq. To reach that target the allowance budget declines annually by 12 Mt (3.4% of average yearly emissions) from 2018 to 2020 and by 13.4 Mt (5% of average yearly emissions) from 2021 to 2030 (ICAP, 2020). No targets have been established in law after 2030, but under current CARB CaT regulations allowance budgets between 2032 and 2050 are set to decline by 6.7 Mt per year from the 2031 cap of 193.8 Mt CO_2e (CARB, 2019a). As the absolute yearly emission reduction remains constant from 2032 to 2050 while the emissions decrease, the annual decline rate (compared to the previous years' emissions) steadily increases, reaching 9.2% by 2050 and a cap of 66.5 Mt. The current cap trajectory aligns with California's 2030 target of 40% below 1990s levels, which is mandated by legislation. California's 2045 target of carbon neutrality was specified by executive order, meaning it could be abandoned or modified by any future governor without a legislative process.

2.1.2 Initial allocation of allowances

California uses a combination of free allocation (about 35%), consignment, and auctioning to distribute allowances (ICAP 2020). Auctioning accounts for about 65% of allocation, with 40% available allowances owned by CARB and 25% consigned to auction by utilities (ibid). Emissions-intensive manufacturers deemed vulnerable to carbon leakage receive free allocation using output-based benchmarking. Carbon leakage vulnerability is assessed through a combination of emissions intensity and trade exposure. Those that are deemed to be at risk receive free allowances based on their recent output, a product-specific benchmark or historic fuel use as a fallback benchmark, and an industry-specific assistance factor.

Electricity-sector entities receive a combination of free allocation and allowances that must be returned – or consigned – to the state for sale at auction but with the resulting proceeds distributed to the original recipients. All proceeds for consigned allowances must be used for the "primary benefit of ratepayers" e.g. rebates to consumers and emissions mitigation that reduces the utility's compliance obligations. The implications of consignment for the electricity sector are discussed in Section 5.

Allocation to electric utilities amounts to about 25% of California's overall allowance budget (CARB, 2019c). Allocation levels until 2020 are determined by a combination of the utility's customer cost burden, anticipated energy efficiency, and early action taken to reduce emissions (CARB, 2010a). Post-2020 allocation is determined based on expected customer cost burdens from program compliance by forecasting the utility's supply and demand, assuming compliance with California's renewable portfolio standard.

The six investor-owned electrical distribution utilities (IOUs) in California must consign all freely allocated allowances to auction. They deliver approximately three-quarters of electricity produced in the state and receive about two-thirds of the sector's share of allowances (CARB, 2019c) (see Section 4 for electricity market characteristics). From 2013-2017 about 96% of consignment proceeds was returned to residential, small business, and energy-intensive and trade exposed consumers, with only 0.4% going towards clean energy investment (ibid). As long as consignment proceeds are returned based on volumetric tariffs, price pass-through would be reduced, particularly for residential customers, who received 82% of revenues from 2013-2017. However, volumetric returns were phased out in 2017, and residential returns are distributed equally across all ratepayers in a manner designed to maintain incentives to reduce usage or improve efficiency (CARB, 2018a). The impact of consignment on the price signal for emissions-intensive industries is likely minimal, as they received only 7% of IOU consignment proceeds from 2013-2017.

Publicly owned electrical distribution utilities (POUs) and electrical cooperatives may choose between holding their freely allocated allowances for compliance or consigning them to auction. The choice is given since they typically own their generating capacity and do not compete with independent operators (see **Fehler! Verweisquelle konnte nicht gefunden werden.** for an overview of capacity owners) to the extent of IOUs (CARB, 2010b). POUs and electrical cooperatives account for approximately one-quarter of the market. From 2013-2017 POUs and electrical cooperatives used 66% of their allowances for compliance and consigned the remainder to auction (CARB, 2019c). Of the 34% of allowances consigned to auction, 13% of proceeds were used to purchase additional allowances at auction[4], 13% for renewable energy and energy efficiency, and 2% returned to ratepayers (ibid). Because POUs and electrical cooperatives are able to determine the share of allowances they use for compliance and return a minimal portion of proceeds to consumers, consignment does not likely significantly impact price signals. Allowance prices are instead largely determined by the degree to which POUs and electrical cooperatives pass on the opportunity cost of freely allocated allowances to customers and the cost of additional allowances purchased at auction.

Auctions are held quarterly. They include allowances owned by CARB, Québec, and the utilities that receive consigned allowances. Auctions of allowances from the current year and unsold allowances from previous years are held separately from auctions of future vintages, known as advance auctions. Consigned allowances are the first to be sold at auction, with consignment entities receiving the proceeds for each of their designated allowances at the settlement price. Notices and results are publicly posted by both California and Québec. An auction reserve price designates a price floor for the year and increases annually. The purchase limit for covered entities is 25% of the total allowances offered for sale at both current and advance auctions.

2.1.3 Banking and Borrowing

Banking is allowed within and across three-year compliance periods, but regulated entities are subject to a holding limit that declines annually based on the current year's cap. Formally, borrowing is not allowed, but entities can purchase allowances from future vintages at current settlement prices that cannot be used for compliance until their year of validity. Regulated entities must surrender allowances annually equal to 30% of the previous year's verified emissions and allowances for the remaining emissions at the end of every three-year compliance period. Thus, there is a form of limited intertemporal-flexibility allowing restricted borrowing within the three-year period.

[4] Effective April 1, 2019, purchasing allowances with consignment proceeds is prohibited (CARB, 2019c)

2.1.4 Provisions for additional allowances supply

Offsets

Offsets are allowed for compliance on a limited basis and only from approved standards, or protocols, established by CARB. Regulated entities can meet up to 8% of their compliance obligations with offsets until 2020. Assembly Bill 398 set further limits between 2021 and 2030. Between 2021-2025 offset usage will decrease to a maximum of 4% of compliance obligations, increasing to 6% from 2026-2030. In addition, starting 2021 half of offsets used for compliance must provide "direct environmental benefits" to California. Assembly Bill 398 defines "direct environmental benefits" broadly as the "reduction or avoidance of emissions of any air pollutant in the state" or pollutants that "could have an adverse impact on waters of the state". The Compliance Offsets Protocol Task Force, whose membership was approved in January 2020, is charged with providing guidance to CARB on establishing new offset protocols with direct environmental benefits to the state. CARB has indicated that it will also review projects from existing protocols for direct environmental benefits (CARB, 2018b).

The six current offset protocols are for US forestry; urban forestry; livestock (e.g. methane management); ozone-depleting substances; mine methane capture; and rice cultivation. CARB has approved 149 million offset credits for compliance as of March 2020, which is equivalent to 6.8 % of total allowance budgets from 2015 to 2020. Most of these credits have come from US forestry projects at 125 million units (84%), followed by ozone-depleting substances at 16 million units (10%). CARB is considering new offset protocols, including wetland restoration and enhanced management or conservation of agricultural and natural lands.

CARB sets detailed requirements for each project type in its offset protocols. Forestry projects, for instance, come with permanence requirements that mandate a buffer account as insurance against reversals of emission reductions due to intentional actions and unintentional causes e.g. wildfire. Buffer requirements are determined based on project-specific risk ratings. Offsets are subject to the principle of "buyer liability", whereby the state can invalidate a credit that is later found to not meet the requirements of the respective offset protocol. Any facility that used an invalidated offset for compliance must substitute with a valid offset credit or allowance.

Offsets are sold under bilateral purchase agreements. CARB does not release data on offset price trends, but in past years they have traded significantly below allowance prices (IETA, 2015). Before the program was extended to 2030 with Assembly Bill 398, offsets sold about 20% below allowance prices on average, but the price gap began to narrow after the bill's passage (Climate Trust, 2019).

Linking

Allowances from Québec are also allowed for compliance. The two programs have been linked since 2014 and hold joint quarterly auctions. Québec's market is significantly smaller, with a cap of 54.74 Mt CO_2eq for 2020 (16% of California's 2020 cap), but with similar sectoral coverage and other regulatory elements, including the same price floor at auctions.[5] Once linked, allowance prices in the two markets have converged. However, a key distinction is that Québec's electricity emissions are close to zero, and the province does not use consignment allocation for any covered entities.

[5] As trades are not reported and allowances are jointly auctioned, i.e., we observe a uniform allowances price and are not able to conclude in which direction the effect goes.

California and Québec were briefly linked to Ontario in 2018, but the election of a new provincial government led to Ontario's withdrawal. California and Québec subsequently suspended trading with Ontario entities and later cancelled more than 13 million allowances to ensure the environmental integrity of their programs.

2.1.5 Market stability mechanisms

California has a number of mechanisms to maintain market stability. An Auction Reserve Price sets a minimum threshold below which bids at auction are not accepted. The Auction Reserve Price increases each year by 5% plus inflation, standing at USD 16.68 in 2020 (and will continue to rise annually).

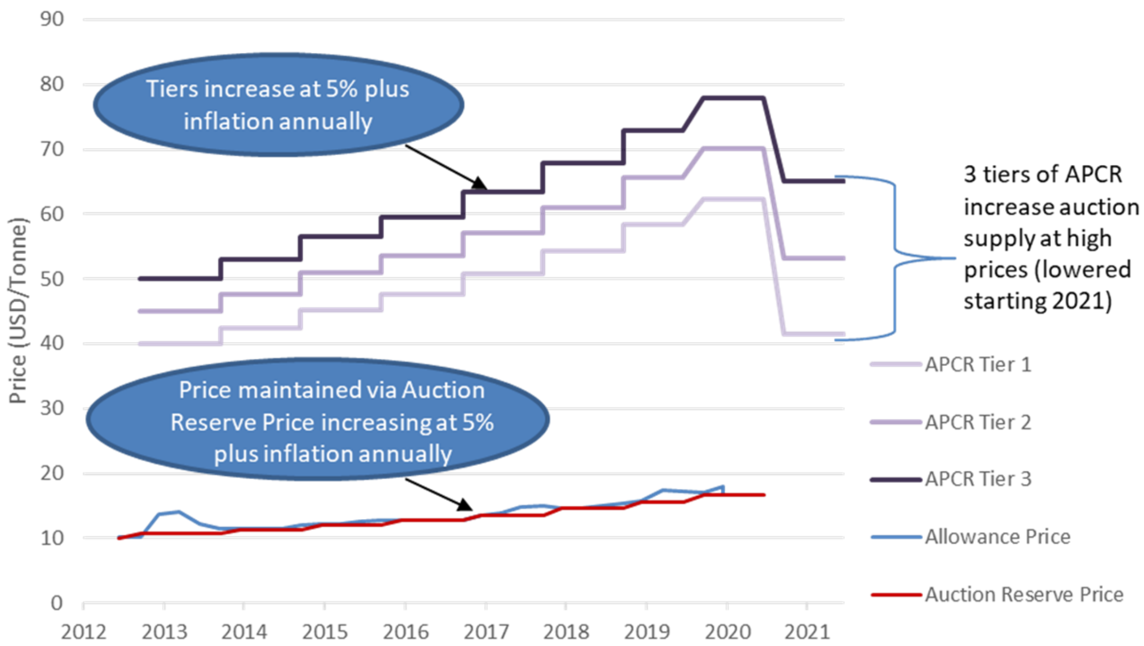
With the exception of several months in 2013 and 2019, settlement prices have rather closely followed the Auction Reserve Price (see Figure 1).

Unsold allowances from previous auctions are reoffered at current auctions if two consecutive auctions result in settlement prices above the Auction Reserve Price. The maximum number of unsold allowances that can be returned is 25 % of the California allowances offered at the current auction. Any unsold allowances above that amount remain in the Auction Holding Account. If allowances remain unsold for more than 24 months, they are placed in the Allowance Price Containment Reserve (Acworth et al. 2020). California has only cancelled allowances in the case of Ontario's 2018 departure from the linked market, which was aimed at maintaining the environmental integrity of the system.

In tandem with a price floor, California operates an Allowance Price Containment Reserve, but it has never been triggered because prices have generally remained near the price floor since the CaT program's launch. The Allowance Price Containment Reserve contains a percentage of yearly allowance budgets, which are released at three different price points that increase annually by 5% plus inflation (see Figure 1). Assembly Bill 398 reforms the price points starting 2021. All three points will be lowered to USD 41.40, USD 53.20, and USD 65.00 respectively, with the last serving as a price ceiling at which covered entities can purchase "price ceiling units" up to their unmet compliance obligations. CARB is required to finance verifiable emissions reductions for each unit sold at the price ceiling on a tonne for tonne basis. CARB has stated that future regulatory amendments will likely be necessary to determine eligibility for emissions reductions purchased from the proceeds of price ceiling units but that possible sources could be state-approved offset credits from uncapped sectors (CARB, 2018b). The three price tiers in the Allowance Price Containment Reserve will continue to increase annually by 5% plus inflation after they are lowered in 2021.

Prices settling at or near the floor price was highly likely from the outset of the program owing to a generous cap in view of strong complementary policies such as renewable portfolio standards, and low price-responsiveness of abatement (Borenstein et al., 2019). According to Borenstein et al. 2019, complementary policies lead to a steep marginal abatement cost (MAC) curve because the cheaper abatement measures will be implemented through complementary policies, i.e., the cheap abatement options will be "cut away" and thus not incentivized through CaT. The authors show that for low reduction targets (as observed in the past) little additional abatement is needed, and thus it was very likely that the California Carbon Allowance (CCA) prices would clear at or near the price floor. When reduction targets become more stringent (as expected in the future), marginal abatement costs are higher as they approach the steeper part of the MAC curve. Given the low price-responsiveness of abatement e.g. due to a lack of scalable cost-effective abatement technologies, it is then likely that prices realize at the price ceiling.

Figure 1: Price stability mechanisms in the California Cap and Trade Program



Notes: APCR is the Allowance Price Containment Reserve, i.e., the price at which additional allowances are released. Assembly Bill 398 lowers the three tiers starting 2021. The Auction Reserve Price for 2021 was not yet set at the time of publication, and allowance price data was only available from the first two quarterly auctions of 2020.
Source: Based on Acworth et al. 2020.

2.1.6 Voluntary cancellation of allowances

California allows for voluntary retirement of allowances, subject to limits of 10,000 units per year in the case of an agreement between a third party not covered under the program and a regulated entity to cancel allowances. So far, this option has been used to reverse the linking with the Ontario system. California and Québec subsequently suspended trading with Ontario entities and later cancelled more than 13 million allowances to ensure the environmental integrity of their programs.

2.2 Demand

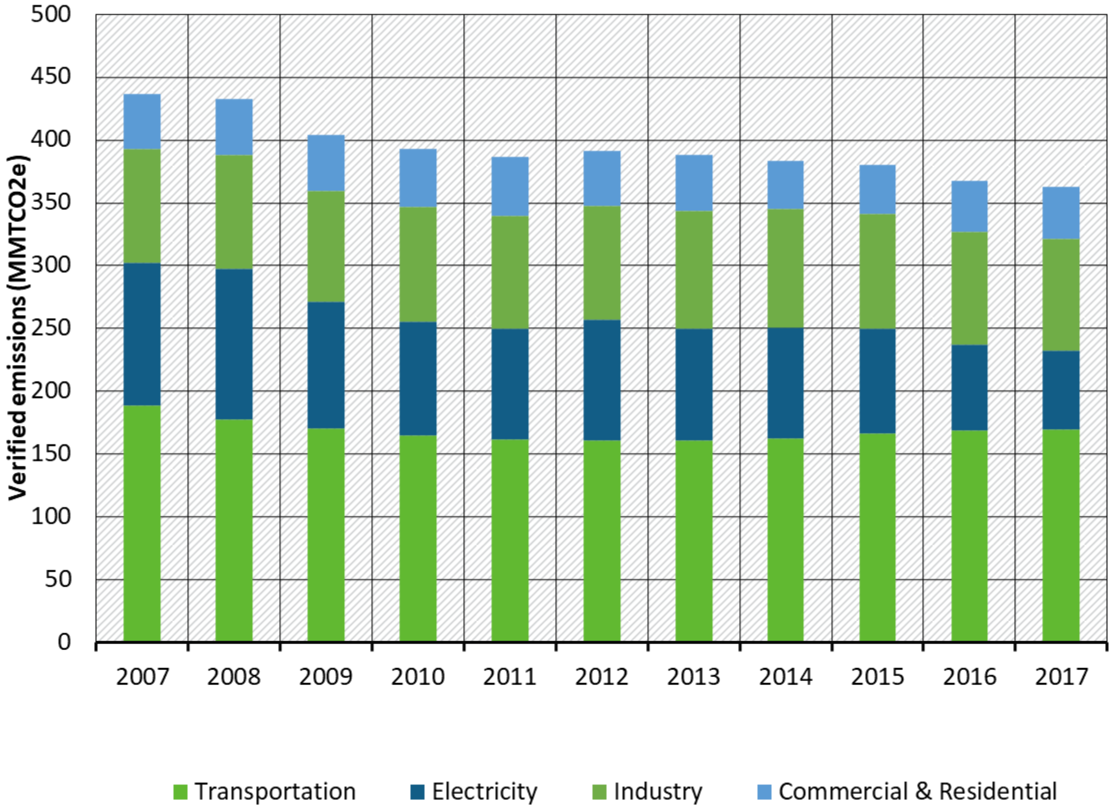
This section describes the demand side features of California's CaT Program.

2.2.1 Coverage

California specifies covered entities by sectors and activities, with an inclusion threshold of 25,000 metric tons of CO_2eq per year. Sectors and activities that are directly covered by the program span manufacturing industries; in-state electricity generation and imports; natural gas suppliers; and suppliers of various transport and heating fuels. Covered gases include CO_2, methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), nitrogen trifluoride (NF_3), and other fluorinated greenhouse gases.

The directly covered sectors correspond to about 363 Mt CO_2eq out of 424 Mt CO_2eq in total GHG emissions, accounting for 86% as of 2017.[6] The largest source of state emissions stems from transport at 169.9 Mt CO_2eq (40%), followed by industry (89.4 Mt CO_2eq, 21%) and electricity (62.4 Mt CO_2eq, 15%) (see Figure 2). Since the start of the CaT program in 2012 only electricity has significantly decarbonized, with modest reductions in the industrial, commercial, and residential sectors.

Figure 2: Verified emissions under the California CaT Program



Source: Own depiction based on California GHG Emissions Inventory Data maintained by CARB (https://ww2.arb.ca.gov/ghg-inventory-data)

Both specified and unspecified electricity imports are covered under the CaT Program. The threshold for specified sources – those that can be traced to a specific source of generation – is 25,000 metric tons of CO_2eq, while any emissions from unspecified imports are covered. Because the emissions-intensity of unspecified sources cannot be precisely verified, California applies a default emissions factor multiplied by a transmission loss correction factor to determine compliance obligations for importers. Resource shuffling, an effort by an electric utility to swap lower-emissions electricity for higher-emissions electricity to reduce compliance obligations, is expressly forbidden in California regulations, though the state has spelled out which practices are safe under CaT regulations.[7]

Imports of transportation and other fuels such as liquefied natural gas are also covered under the CaT program and subject to reporting requirements.

[6] See California GHG Emission Inventory Data maintained by CARB: ww2.arb.ca.gov/ghg-inventory-data
[7] See section 95852(b)(2)

2.2.2 Market participation

The California system is open to participation by non-regulated entities. Other participants can apply to become "voluntarily associated entities", which is broadly defined as any entity that does not face mandatory compliance obligations or has opted into the system as a regulated facility. A participant that successfully registers as a voluntarily associated entity can purchase, hold, sell, or voluntarily retire allowances.

2.3 Transaction and market oversight rules

2.3.1 Legal nature of allowances

Unlike many other jurisdictions with an emissions trading system, California chose to clarify the legal nature of allowances from the outset. In the regulatory framework of the Californian emissions trading system, which has been operationalized through a series of provisions in the California Code of Regulations, a 'California Greenhouse Gas Emissions Allowance'[8] is defined as 'a limited tradable authorization to emit up to one metric ton of CO_2e.'[9] Based on the choice of words, this definition already reveals the intention of the legislator to circumscribe the rights vested in an allowance. As the provision goes on to state, moreover, no provision 'of this article[10] may be construed to limit the authority' of the regulator to 'terminate or limit such authorization to emit'; any doubts as to whether an allowance could confer a legal entitlement are, finally, eliminated by the addition that an allowance 'does not constitute property or a property right.'[11]

With this language, California follows a precedent set at the federal level with the 1990 amendment to the Clean Air Act, which established an emissions trading system to control acid deposition ('acid rain') and contains a very similar passage on the legal nature of allowances.[12] Several documents issued by the State of California shed light on the reasoning behind this narrow definition of allowances. In a supplemental brief issued as part of judicial proceedings against the emissions trading system, for instance, the Californian Department of Justice clarified that, while 'private parties treat allowances … as valuable intangible assets or tradable commodities', the statement that no property rights attach to them was 'necessary to clarify that, vis-à-vis the state, regulatory and enforcement actions … do not give rise to a constitutional takings claim.'[13]

[8] The actual term used is 'compliance Instrument issued by the Executive Officer', which encompasses both allowances and offset credits issued by the Air Resources Board (ARB), see California Code of Regulations, Title 17, Chapter 1, Subchapter 10 (Climate Change), Article 5 (California Cap on Greenhouse Gas Emissions and Market-Based Compliance Mechanisms), Section 95802(a).
[9] California Code of Regulations, Title 17, Chapter 1, Subchapter 10, Article 5, Section 95820(c).
[10] 'Article', in this context, means Article 5 of Title 17, Chapter 1, Subchapter 10 of the California Code of Regulations, and thus encompasses all provisions on the Californian emissions trading system set out in the Code.
[11] California Code of Regulations, Title 17, Chapter 1, Subchapter 10, Article 5, Section 95820(c). 'Property right', in this context, is defined broadly to include any type of right, including personal or real, tangible or intangible property, see ibid., Section 95802(a).
[12] United States Code, Title 42, Chapter 85 (Air Pollution Prevention and Control), Subchapter IV-A (Acid Deposition Control), Section 7651b (Sulfur Dioxide Allowance Program for Existing and New Units) (f): 'Nature of Allowances: An allowance allocated under this title is a limited authorization to emit sulfur dioxide in accordance with the provisions of this title. Such allowance does not constitute a property right. Nothing in this title or in any other provision of law shall be construed to limit the authority of the United States to terminate or limit such authorization.'
[13] State of California, Department of Justice, Office of the Attorney General Kamala D. Harris, Supplemental Letter Brief of Respondents California Air Resources Board, et al. in *California Chamber of Commerce et al.*

Likewise, the Initial Statement of Reasons (ISOR) accompanying the relevant legislative proposal, in which the Air Resources Board (CARB) had already explained that it 'is necessary … to retain authority to terminate or limit the "authorization to emit" so that in the case of fraud or market manipulation' the regulator 'has a mechanism to protect the market.'[14] Similarly, the subsequent Final Statement of Reasons (FSOR) clarified that the Air Resources Board 'needs broad authority to limit or terminate the allowances to ensure that, in the event of any violations, fraud, or other malfeasance in the conduct of the allowance market, it can be immediately addressed.'[15]

Both the clear wording of the legislative language as well as these explanatory statements confirm that the regulator sought to reserve for itself broad discretion to terminate, revoke, or limit allowances without the constraints that ordinarily restrict the ability of an agency to confiscate private property, that is: to deprive persons of their property without due process of law and take private property for public use without just compensation.[16] An additional concern, however, seems to have also motivated the inclusion of the narrow legal definition in the California Code of Regulations, and that is uncertainty about the possibility of future climate legislation at the federal level: in its ISOR, the CARB pointed to the fact that, 'in the event of federal preemption in the cap- and-trade market or other conditions, California must have the ability to revoke the compliance instruments without creating a loss to the people of California.'[17]

The fact that Californian allowances do not confer property or a property right gained practical significance when several plaintiffs unsuccessfully challenged the CaT Program in 2013 because, as they saw it, the requirement to purchase emissions allowances constituted a tax that had not been properly authorized by the State legislature and was therefore illegal under the California Constitution.[18] As the plaintiffs argued, because allowance purchasers could not acquire an ownership interest in the allowances and only obtained a limited authorization that is subject to termination, revocation, or limitation, the need to purchase allowances at auction in order to comply with obligations under the emissions trading system was akin to the imposition of a tax.[19]

Both the Superior Court and the Court of Appeal of the State of California rejected that interpretation, with the latter court arguing that the purchase of allowances was voluntary and did not bear the 'hallmarks' of a tax because allowances were 'valuable, tradable commodities,

v. California Air Resources Board et al. (Case No. C075930) and *Morning Star Packing Company et al. v. California Air Resources Board et al.* (Case No. C075954), 23 May 2016, available at <https://www.edf.org/sites/default/files/content/arbsuppbrief.pdf> at p. 2.

[14] California Environmental Protection Agency, Air Resources Board, Proposed Regulation to Implement the California Cap-and-Trade Program. Staff Report: Initial Statement of Reasons, 28 October 2010, available at <https://ww3.arb.ca.gov/regact/2010/capandtrade10/capisor.pdf> at p. IX-18.

[15] California Environmental Protection Agency, Air Resources Board, California's Cap-and-Trade Program. Final Statement of Reasons, October 2011, available at <https://ww3.arb.ca.gov/regact/2010/capandtrade10/fsor.pdf> at p. 727.

[16] On these, see Constitution of the United States, Fifth and Fourteenth Amendments.

[17] See California Environmental Protection Agency, Staff Report: Initial Statement of Reasons, supra, note 14.

[18] *California Chamber of Commerce et al. v. California Air Resources Board et al.*, Superior Court of California, County of Sacramento, Case No. 34-2012-80001313, Petition for Writ of Mandate (13 November 2013); *Morning Star Packing Co. et al. v. California Air Resources Board et al.*, Superior Court of California, County of Sacramento, Case No. 34-2013-80001464, Petition for Writ of Mandate (16 April 2013).

[19] Ibid.

conferring on the holder the privilege to pollute.'[20] One justice dissented, however, contributing to the insistence of former Governor Edmund Gerald Brown Jr. that legislation extending the emissions trading system be adopted with a supermajority, a voting threshold required to pass legislation introducing a tax. That supermajority now shields the emissions trading system against any challenges that it is a measure of a fiscal nature and was thus not passed with the required voting threshold under Californian law.

2.3.2 Fiscal nature of allowances

In the U.S., the power to levy taxes is shared between the federal, state and local governments,[21] with the majority of revenue accruing to the federal level.[22] As a result, what rules and practices on the tax treatment of allowances exist – including guidance from the relevant federal agency, the Internal Revenue Service (IRS) – have primarily evolved at the national level rather than on a state-by-state basis. Questions related to federal taxation involve, notably, how and when allowances allocated for free will be taxed, how to determine the tax basis of allowances, whether the cost of acquiring an allowance should be capitalized or deducted, when and how any capitalized costs are to be recovered, and the character of any gains and losses recognized on sale or exchange of allowances.[23] At the state and local level, additional questions can arise with regard to the application of sales tax.

IRS guidance on allowances issued under the Clean Air Act stipulates that the costs of acquiring allowances must be capitalized, establishing the taxable basis;[24] if the allowances are subsequently surrendered for compliance, the basis can be deducted that year. If, instead, they are sold or exchanged, the allowance holder will realize a capital gain or loss to the extent of the difference between the basis and the amount realized in the transaction.[25] Emissions allowances allocated free of charge receive a zero basis and are thus not taxed as gross income,[26] but will be taxed on the full amount of the sales proceeds,[27] meaning that the taxation of free allowances is merely deferred.[28] Allowances are not subject to amortization or depreciation, moreover, because the allowances have no ascertainable useful life over which they could be depreciated.[29]

[20] *California Chamber of Commerce et al. v. California Air Resources Board et al.* and *Morning Star Packing Co. et al. v. California Air Resources Board et al*., Court of Appeal of the State of California, 3rd Appellate District, Cases No. C075930 and C075954, Opinion (6 April 2017), at p. 4.
[21] See, generally, Bruce Ackerman, 'Taxation and the Constitution', 99 *Columbia Law Review* (1999:1), p. 1 et sqq.
[22] In 2019, for instance, federal receipts were 65 percent of total tax revenue, while state and local receipts (excluding inter-governmental transfers) were 20 percent and 15 percent, respectively, see United States Bureau of Economic Analysis, 'National Income and Product Accounts', Section 3, Tables 3.2 and 3.3 (26 March 2020).
[23] Congress of the United States, Joint Committee on Taxation, 'Climate Change Legislation: Tax Considerations (JCX-29-09)' (12 June 2009), available at <https://www.jct.gov/publications.html?func=download&id=3559&chk=3559&no_html=1>, at p. 5.
[24] Internal Revenue Service, Revenue Procedure 92-91, supra, note 21.
[25] Ibid.
[26] Internal Revenue Service, Revenue Ruling 92-16, supra, note 21; this interpretation is not automatic, given that a general principle of tax law states that any 'undeniable accessions to wealth, clearly realized' is income to a taxpayer, see Supreme Court of the United States, *Commissioner v. Glenshaw Glass Co.*, 348 *United States Reports* 426 (1955).
[27] See United States Code, Title 26 (Internal Revenue Code), Subtitle A (Income Taxes), Section 1001.
[28] For discussion, see Gary M. Lucas, Jr., 'The Taxation of Emissions Permits Distributed for Free As Part of a Carbon Cap-and-Trade Program', 1 *George Washington Journal of Energy & Environmental Law* (2010:5), at p. 16.
[29] Internal Revenue Service, Revenue Procedure 92-91, supra, note 21.

Additional guidance from the IRS has determined that allowances are not tangible property.[30] Rather, as the Joint Committee on Taxation of the U.S. Congress has held, they are 'transferable, intangible assets, the useful life of which can be limited by statute.'[31] Allowances issued by a foreign jurisdiction – the European Union – have likewise been considered an intangible asset by the IRS.[32] IRS guidance and additional sources thus offer insight into the capitalization, depreciation, sales and exchanges of emissions allowances, but still leave important questions unanswered – including treatment under state and local taxes, where documentation so far is sparse – and need updating in view of subsequent changes to the Internal Revenue Code.[33] With no legislative efforts to adopt a federal emissions trading system currently underway, the discussion about tax treatment of allowances – which was fairly active during 2008-2010 – has become dormant, and both regulated entities and other market participants as well as the IRS have contended with the lingering uncertainty by applying the guidance on tax treatment of SO_2 and NO_x allowances.

2.3.3 Market places

Allowances are mainly exchanged during quarterly allowances auctions. The Intercontinental Exchange (ICE) is the main platform for the secondary market. According to interview partners, compliance entities mostly buy their allowances at auctions, i.e., secondary markets do not play a major role in allowances exchange.

2.3.4 Transparency regulation

According to the CaT legislation 'Emissions data submitted to ARB … is public information and shall not be designated as confidential'[34]. Consequently, verified emissions on an installation level are published in a transparent way on the webpage of the CARB[35] and, together with other pollution data, in a graphical form via the CRBO Pollution Mapping Tool[36]. Free allocation is published summarized by economic sector together with installation names and also by electricity distribution facilities.[37] Moreover, auction outcomes as well as information on offset projects are published by CARB.[38] Detailed information on allowance transactions is not available.

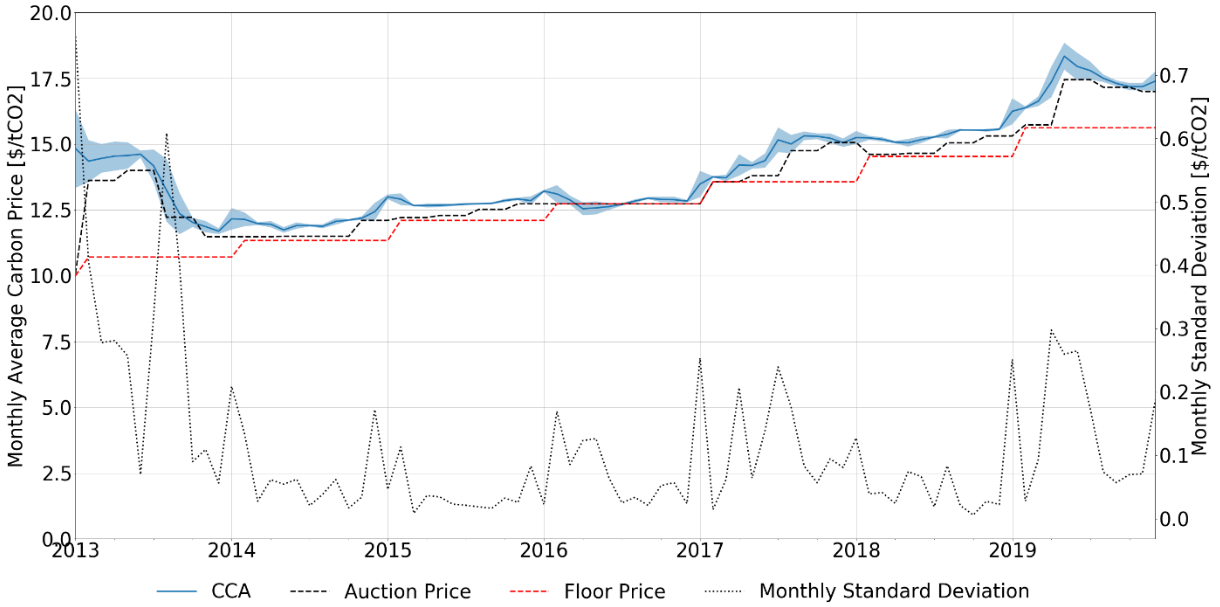
[30] Internal Revenue Service, Private Letter Ruling 200728032 (5 April 2007), at p. 4.
[31] Congress of the United States, Joint Committee on Taxation, 'Climate Change Legislation: Tax Considerations (JCX-29-09)', supra, note 23, at p. 6.
[32] Specifically, and contrary to the definition in U.S. federal and Californian law, allowances were considered intangible property, see Internal Revenue Service, Private Letter Ruling 200825009, supra, note 21, p. 5.
[33] Annette Nellen, 'Tax Aspects of Greenhouse Gas Legislation' (13 August 2009), available at https://www.aicpastore.com/content/media/PRODUCER_CONTENT/Newsletters/Articles_2009/Tax/GreenhouseGas.jsp.
[34] California Code of Regulations, Title 17, Chapter 1, Subchapter 10, Article 5, Section 96021(a).
[35] https://ww2.arb.ca.gov/mrr-data.htm
[36] https://ww3.arb.ca.gov/ei/tools/pollution_map/pollution_map.htm
[37] https://ww3.arb.ca.gov/cc/capandtrade/allowanceallocation/publicallocation.htm
[38] https://ww3.arb.ca.gov/cc/capandtrade/capandtrade.htm

3 Assessing the ETS Design and the Quality of the Allowance Price

Figure 3 provides allowance prices at both California's state-run auctions, represented by the dashed line, and on the secondary market, denoted by the blue line tracking developments in California Carbon Allowances (CCA). Since the introduction of the CaT, prices have been rather stable with a slightly increasing tendency. This increase can most likely be explained by the systems' minimum price: With the expection of several months in 2013, 2017, and 2019, CCA prices have rather closely followed the Auction Reserve Price (see Figure 1).

Short-term volatility, defined as the monthly standard deviation of the allowance price in secondary markets, is measured on the right axis and represented by the dotted line below the price developments. Figure 3 shows that price volatility in the short-run, i.e., on a monthly level, as well as in the long-run is low. The highest monthly standard deviation of 0.76 $/t$CO_2$ occurered near the outset of the program at a price level of about 15 $/t$CO_2$ and maximum short-run volatility was merely about 5% of the price. Long-term volatility was also not very high but prices have gradually increased.

Figure 3: California Carbon Allowances (CCA) Prices



Note: Shown are nominal monthly average CCA prices on secondary markets (blue line) together with the 95% confidence interval, i.e., the range in which 95% of the price values realized. The corresponding standard deviation (dotted black) is measured on the right axis. Dashed lines show the results of quarterly auctions with the realized price in black and the price floor, i.e., the auction reserve price, in red.
Source: Own depiction based on California system operator CAISO for daily CCA price index (http://oasis.caiso.com/mrioasis/logon.do). Auction prices are based on auction results provided by California Air Resource Board (https://ww3.arb.ca.gov/cc/capandtrade/auction/auction.htm).

3.1 Volatility

With the exception of an early period of volatility in the first year of compliance obligations, allowance prices at California auctions have remained stable, generally clearing at or near the price floor (Auction Reserve Price), which increases by 5% per year plus inflation. Early auctions in 2013 were characterized by high demand, with nearly two bids received for every available allowance (Shen et al., 2014). In the last two quarters of 2013, however, prices declined significantly before stabilizing around the price floor and entering a long period of relative stability. The factors behind this early volatility in 2013 are not definitively clear. One potential factor was a growing perception among market participants that the CaT program was oversupplied. Market participants reacted strongly to a report by the industry and market analysis firm Point Carbon in September 2013, which dramatically lowered its projections of price developments (EDF, 2014). The analysis concluded prices would likely remain near the price floor through 2020 because of complementary policies such as the state's renewable portfolio standard, a slow economic recovery, and other factors.

Ex-ante projections of emissions trajectories for cap-setting, especially in conjunction with strong complementary policies, is generally regarded a challenge for emissions trading systems (Burtraw & Keyes, 2018; Borenstein et al., 2019). Other market analysts argued in response that lower prices were always anticipated because the market was oversupplied by design to ensure smooth implementation of the program (EDF, 2014). A gap between reported actual emissions in the early years of the program and cap levels also contributed to the perception of market "softness" (Borenstein et al., 2019; Yang et al., 2017).

Regarding the impact of different design elements of the CaT on volatility, it is difficult to draw firm conclusions due to the low level of volatility. Nevertheless, we provide some descriptive evidence in the following:

- **Primary allocation:** We do not observe changes in the mode of primary allocation. Thus, it is difficult to conclude about its impact. However, the necessity to consign part of freely allocated allowances to auctions leads to a high volume of allowances in quarterly auctions. ICAP (2020) reports that 65% of 2019 allowances have been available through auctions.
- **Provision for additional allowance supply**: Neither linking with the Québec system in 2014 nor the abrupt departure of Ontario from the linked market in the latter half of 2018 seem to have impacted the short-run volatility. Also, there is no evidence that offsets have impacted volatility. In the CaT system, therefore, the provision of additional allowances does not seem to have impacted volatility.
- **Market Stability Mechanisms:** Key determinants of price levels have been and will likely remain the long-term target set by the declining cap and market stability mechanisms. As mentioned in section 2.1.5, prices settling at or near the floor were highly likely from the outset of the program, the impact of complementary policies, and low price-responsiveness of abatement (Borenstein et al., 2019). These factors have elevated the importance of California's market stability mechanisms in managing volatility and have largely done so successfully, as prices have increased gradually, largely in step with the rising Auction Reserve Price. The effectiveness of California's complementary policies for key sectors, including renewable portfolio and low-carbon fuel standards, will also continue to play a strong role in the system's long-run price trajectory. To conclude, the CaT system provides evidences that a price corridor, in particular in conjunction with complementary policies (which decrease the demand for allowances), has a strong tendency to decrease short-term price volatility, as the floor supports prices at the reserve price.
- **Coverage:** In 2015 the system coverage was extended to include transportation and heating fuels. Volatility does not seem to be affected by this regulatory change.

- **Market participation:** Interview partners stated that regulated entities do not participate much in the secondary market. In fact, the number of transactions was just 524 in 2019, the highest year on record.[39] Interview partners said that one reason for this low number might be that electricity producers do not have a tradition of profit-driven trading of fuels and other inputs but rather to procure the amount necessary for production. Another reason might be the above described effect of consignment of free allocation to auctions.

3.2 Reflection of MAC

In theory, an undistorted allowance price that equals the marginal abatement cost (MAC) of all market participants would serve as a high-quality price signal. In such a situation the price is determined by the marginal supplier of abatement. The CaT has some features that according to theory (Acworth et al., 2019) have a positive impact on the reflection of MAC: e.g. auctioning of allowances in the electricity sector and quarterly auctions with a high volume due to consignment. Given the high coverage (80% of total emissions), one could assume that the carbon price reflects the MAC of (almost) the whole economy.

In practice, the price for Californian allowances seems to be mostly determined by the level and development of the auction reserve price (see 2.1.5). Experts agree that the market clearing price was "artificially" kept low by the implementation of many mandated programs, such as the renewable portfolio standard or the emission performance standard (see Section 4.3). These complementary policies significantly reduce emissions of covered entities and thus are decreasing the demand and the carbon price (Borenstein et al. 2019).

One expert argues that the carbon price reflects the "conditional MAC", meaning that the market clearing price equals MAC conditional on all other incentives, such as the renewable or emission performance standards. He argues that the real MAC is a combination of the carbon price plus the hidden costs of the complementary policies, which are different for each sector. Given that the product price is only directly affected by the carbon price, climate policies are cheaper from a consumers' perspective.

3.3 Long-term predictability

In the past, the carbon price mostly followed the floor price. There are mainly two design elements that influence long-run predictability of the carbon price:

- **Long-term target:** The announcement of long-term targets is crucial for the predictability of the price. Before the year 2017, there was no cap set beyond 2020. This might be one reason why prices were at the price floor during 2014 to 2016. As soon as the rules and cap were put in place in 2017, prices slightly increased. Concerning future caps, the 2030 target of 40% below 1990 levels has been adopted, whereas the carbon neutrality target for 2045 has only been specified by executive order of a former California governor, i.e., it is not yet legislatively mandated. Therefore, there is still a regulatory risk about the stringency of future caps.
- **Market Stability Mechanisms:** By design, a price corridor has a large impact on predictability of carbon prices. Generally, as long as price floors and ceilings are not changed by market reforms, they help to reduce the allowance price risk.

[39] https://ww3.arb.ca.gov/cc/capandtrade/2019transfersummaryfinal.xlsx

In the past, the floor price (Auction Reserve Price) has proven to be a reliable price forecast. Given the more stringent targets for the future, some experts expect carbon prices to increase. A study cited by many interview partners shows that prices are likely to be at the market's administrative extremes, the floor or ceiling (Borenstein et al., 2019). Overall, the price corridor reduces the possible future price range and, thus, increases the predictability of the allowances price.

- **Provision of additional allowances supply:** Given that additional supply in the form of offsets needs to be forecasted, the predictability decreases with the use of offsets. Likewise, the linking can have a (negative) impact on the quality of the (domestic) price signal as it also makes demand forecasting more complicated.

Next to the design of the CaT itself, interview partners stress the importance of additional policies. They mostly agree that by implementing many mandated programs (e.g. renewable portfolio standard or energy efficiency programs in the electricity sector, but also standards in the transportation and other sectors) the price of the CaT was kept low, which had a positive impact on the political feasibility of the program. Some experts believe that due to this practice in the past, it was possible to establish a framework, which will remain stable in the future - even when targets become more stringent.

Generally, the system is perceived as stable. According to experts, this is the case as the market design was informed by lessons learnt from the deregulation of the electricity market on the one side, and experiences from the European Emission Trading System (EU ETS) on the other side.

3.4 Environmental effectiveness of ETS

The environmental effectiveness of the CaT is affected, if the allowances supply is changed by a design feature. Given the nature of a cap-and-trade system, only features that change the cap impact the effectiveness of the system: First, the use of offset credits increased allowances supply in CaT by 149 million units from 2015 to March 2020 (around 6.8% of the average yearly allowances budget). Allowing offset usage therefore decreased the domestic environmental effectiveness of the system as they have traded significantly below allowance prices (see section 2.14). There is no information on the impact of linking with the Quebec system, but since the system is rather small compared to the CaT, the impact will be limited.

The auction reserve price, on the other side, tightens supply and might change domestic environmental effectiveness. If prices are below the price floor, the amount of auctioned allowances is reduced until the price floor is reached. Withdrawn allowances are transferred into the reserve. It is however not foreseen that allowances are permanently canceled out of the reserve. If (one of) the price ceilings is exceeded, allowances are released from the reserve again. Thus, in its current form, the price corridor does not alter the environmental effectiveness of the system, as unsold allowances are set aside but not cancelled out of the system. However, if the hard price ceiling becomes effective in the future, this could weaken the environmental effectiveness of the system. Yet, according to interview partners, it is likely that CARB will try to prevent reaching the hard price ceiling by introducing additional complementary policies. Thus, except for this currently uncertain point, the Californian price corridor does not alter the cumulative emission target and hence does not alter environmental effectiveness.

4 Introduction to electricity market

4.1 Market design and structure

4.1.1 Market Design

Deregulation of California's electricity market started in the mid-1990s. After the California electricity crisis in 2000-2001, deregulation partially stopped. What remains is a partially deregulated system. On the one hand, the wholesale market is liberalized and generation and transmission assets are unbundled. In a centralized dispatched system, the independent transmission system operator (CAISO) dispatches power plants based on their bids in the wholesale markets. On the other hand, only a fraction of final consumers is allowed to freely choose their suppliers. Whereas, retail electricity prices are not regulated, they are under regulatory oversight. In the following, we described these features in greater detail together with the structure of the market in terms of capacity, generation, and market players.

4.1.2 Market Structure and Dynamics

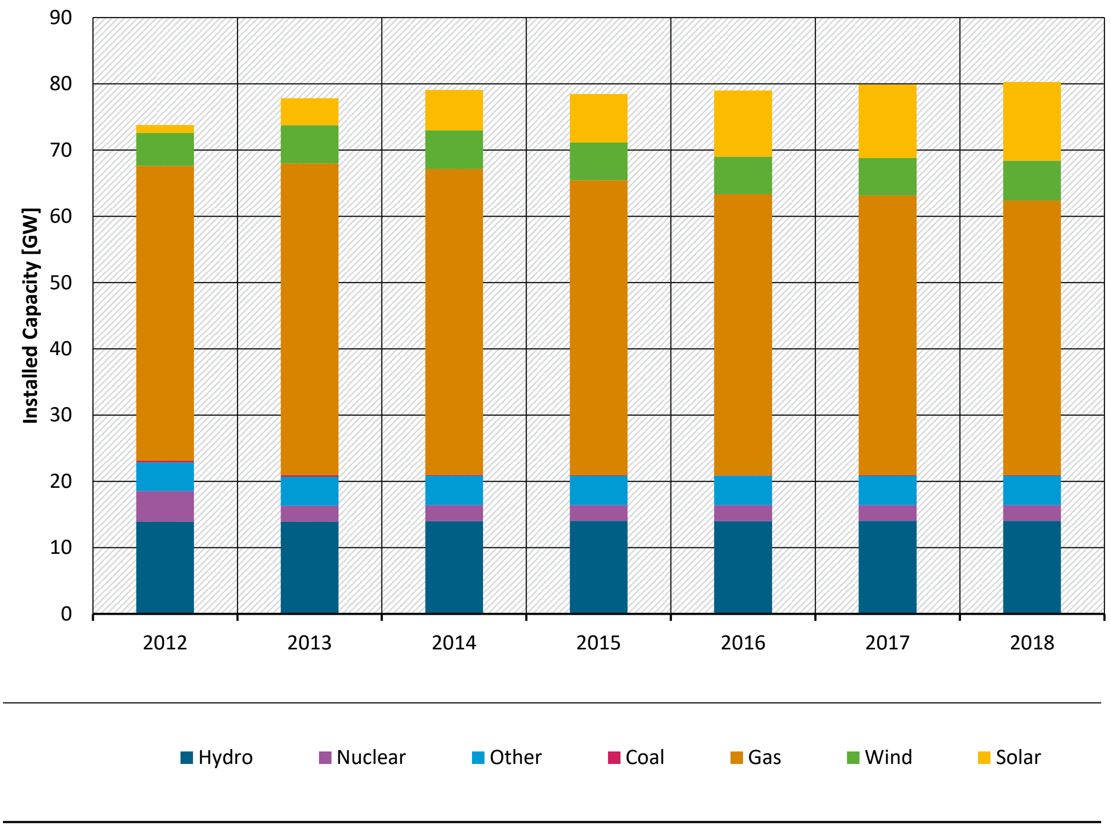
Capacity mix, investments and age of plant fleet

Installed generation capacity in California is dominated by gas-fired power plants (see Figure 4). As coal-fired power plants do not play a role in California, gas-fired power plants are the only carbon-based generation technology. Since the introduction of emissions trading in 2013, gas capacity decreased by 3 GW to 41.5 GW in 2018.
Hydro generation capacity remains constant since 2012. After the shut-down of the San Onofre Nuclear Generating Station (SONGS) power plant in 2012, nuclear capacity also remains constant. Davis and Hausmann (2016) report, that the SONGS closure led to an increase of carbon emissions about 9 MtCO_2 in the year 2012. From 2013 onwards, these emissions have been regulated under the emissions trading system.
Renewable capacity, in particular solar PV capacity[40], increased from 2013 onwards. Whereas this might be partly attributed to the introduction of emissions trading in 2013, the major reason is likely to be the tightening of renewable standards in 2011 (see below).

Figure 5 provides a breakdown of the installed capacity in 2018 according to the decade of installation. Hydro capacities are rather old. Most of them have been installed in the 80s and before. Besides SONG closed in 2012, the Diablo Canyon Nuclear Power Plant operated by Pacific Gas and Electric Company (PG&E) is the only nuclear power plant in California. The 2.4 GW became operational in 2013. Gas-fired capacity is diverse in age. Major investments have taken place in the early 2000s, i.e., after the liberalization and unbundling of the electricity market, and the subsequent California electricity crisis.

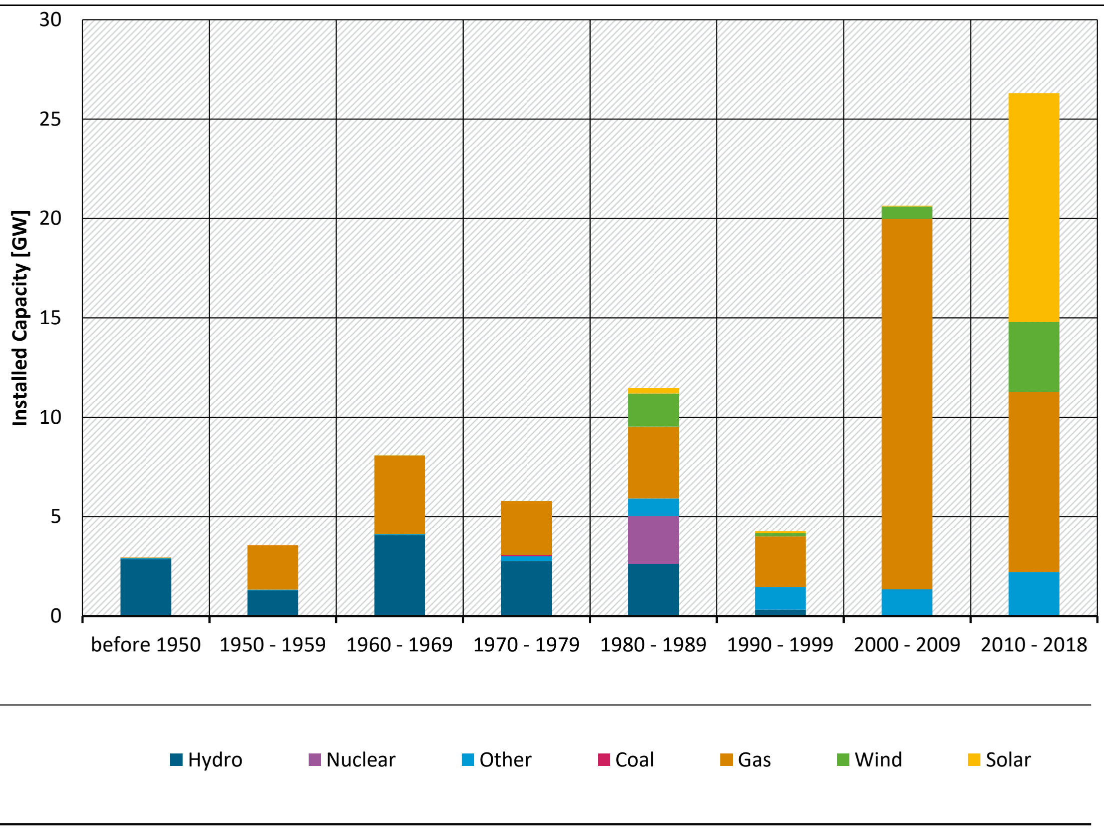
[40] In 2018, out of the 12 GW solar capacity installed, 10.5 GW was solar PV and the remaining part solar thermal.

Figure 4: Installed Capacity



Source: Own depiction based on California Energy Commission: ww2.energy.ca.gov/almanac/electricity_data/electric_generation_capacity.html

Figure 5: Installed Capacity by Installation Year (in 2018)



Source: Own depiction based on California Energy Commission: https://ww2.energy.ca.gov/almanac/electricity_data/generating_units.html.

Ownership and Market Concentration

Capacity owners

Table 2 shows the installed capacities by owners and technology type. The largest five generators own 27% (37%) of total (conventional) capacity. This low market concentration is the result of the liberalization of the Californian power market in the beginning of the 2000s that required large incumbents to sell their generation assets. Remarkably, large generators concentrate on conventional capacity whereas renewable capacity is almost entirely owned by smaller companies. Table 3 draws a similar picture in terms of generation. The largest five generators possess a combined market share of 31% (40%) in total (conventional) generation.

Table 2: Installed capacity by market actor and technology in 2018 [GW]

	Coal	Hydro	Gas	Nuclear	Other	Solar	Wind	Total
Pacific Gas & Electric	-	3.9	1.5	2.4	-	0.2	-	7.9
L. A. Dep. of Water & Power	1.8	2.0	3.9	-	0.0	0.0	0.1	7.8
U.S. Bureau of Reclamation	-	4.1	-	-	-	-	-	4.1
Southern California Edison	-	1.1	1.3	-	-	0.1	-	2.5
GenOn Holdings	-	-	2.2	-	-	-	-	2.2

Source: Own calculations based on California Energy Commission: ww2.energy.ca.gov/almanac/electricity_data/web_qfer/Annual_Generation-Plant_Unit_cms.php. Data also include plants not located directly in CA but operated by the respective company leading to a difference between this table and statistics for the state of California (Figure 4). Most importantly, coal capacity almost entirely represent the Intermountain Power Plant located in Utah but connected by a HVDC cable to CA.

Table 3: Generation by market actor and technology in 2018 [TWh]

	Coal	Hydro	Gas	Nuclear	Other	Solar	Wind	Total
Pacific Gas & Electric	-	7.4	6.3	18.3	-	0.3	-	32.3
L. A. Dep. of Water & Power	8.5	0.7	6.4	-	0.0	0.0	0.3	15.9
U.S. Bureau of Reclamation	-	7.8	-	-	-	-	-	7.8
Sacramento Mun. Utility Dist.	-	1.3	4.9	-	-	-	-	6.2
Geysers Power Company	-	-	-	-	5.7	-	-	5.7

Source: Own calculations based on California Energy Commission: https://ww2.energy.ca.gov/almanac/electricity_data/web_qfer/Annual_Generation-Plant_Unit_cms.php. Data also include plants not located directly in CA but operated by the respective company leading to a difference between this table and statistics for the state of CA. Most importantly, coal capacity almost entirely represent the Intermountain Power Plant located in Utah but connected by a HVDC cable to CA. Thus, coal generation shown here is not reflected in the state generation (Figure 6) but in imports (Figure 7).

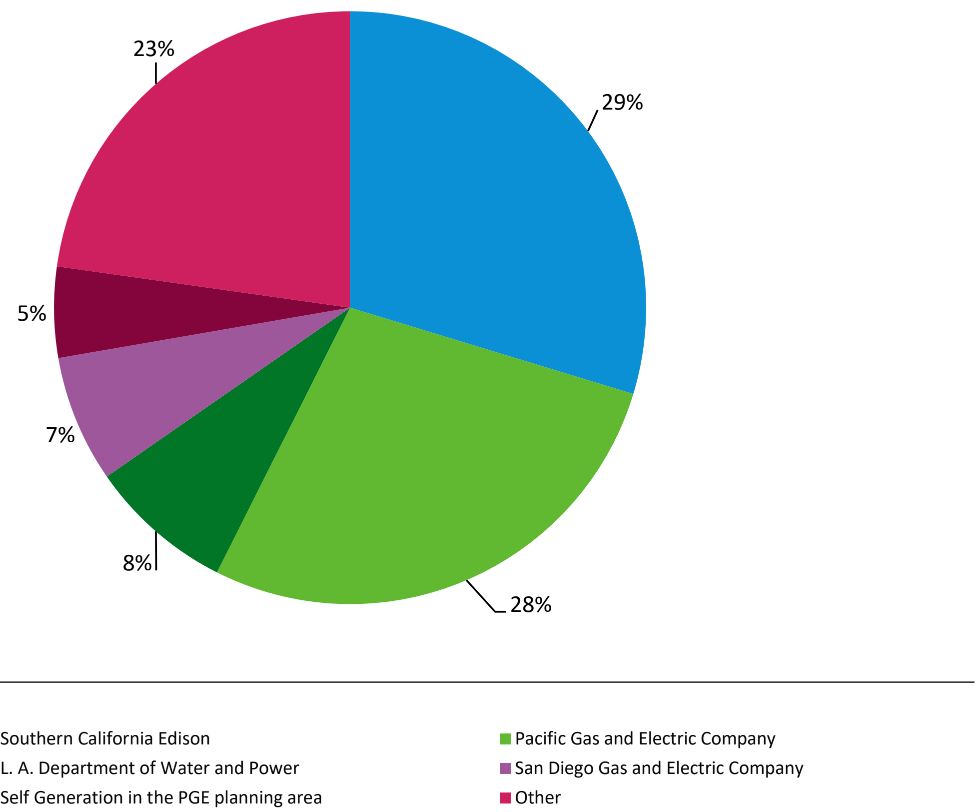
Utilities

There are two different types of electricity and natural gas providers[41]: First, investor-owned utilities (IOUs) are private providers, which are overseen by the California Public Utilities Commission (CPUC). Three IOUs (Pacific Gas and Electric, San Diego Gas and Electric, and Southern California Edison) account for around three quarters of electricity supply in California. Second, publicly owned utilities (POUs) are subject to local public control and regulation. POUs are generally smaller than IOUs. They are organized in various forms including municipal districts, city departments, irrigation districts, or rural cooperatives. More than 40 POUs in the state account for around one quarter of electricity supply in California. Both, IOUs and POUs, can have own generation facilities or purchase power through contracts.

Figure 6 shows the retail market shares of the five largest companies. The combined market share is 77% with 5%, however, accounting for self-generation.

Overall, we can conclude that the generation side of the Californian wholesale market seems to be rather competitive.[42] On the retail market side, former incumbents still have a high market share.

Figure 6: Retail Market Shares 2018



Source: Own depiction based on California Energy Commission: http://www.ecdms.energy.ca.gov/

[41] https://ww2.energy.ca.gov/pou_reporting/background/difference_pou_iou.html

[42] Whereas there might be concerns that the nodal structure of the market allows exerting local market power, this is prevented by checking individual bids in the wholesale market as described above.

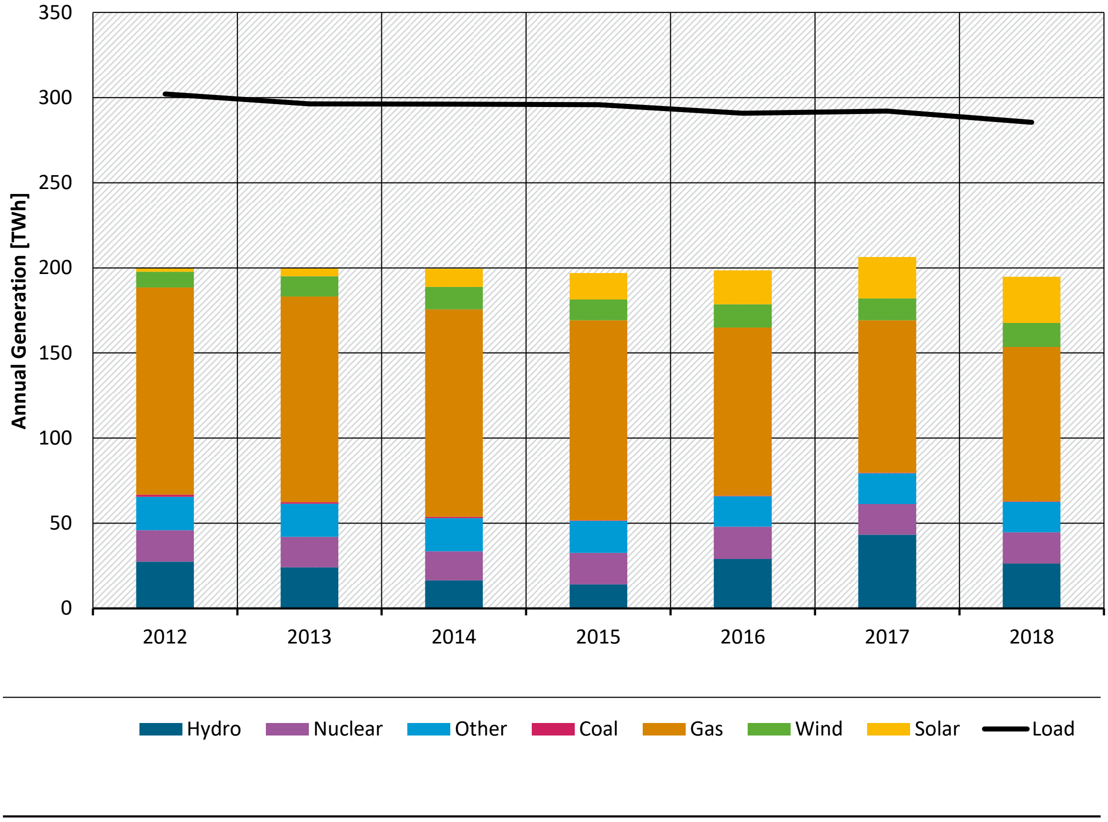
Concerning ownership, out of the five largest capacity owners (see Table 3) only the L.A. Department of Water and Power is a publicly owned utility, whereas the remaining companies are investor owned. In terms of generation, the Sacramento Municipal Utility District is also publicly owned. In the retail market, investor owned utilities have a market share of 65% followed by publicly owned utilities with about 28%.[43] We therefore conclude that ownership is rather mixed between publicly and privately owned utilities.

Electricity generation and demand

The generation mix mimics the capacity mix (Figure 7). Except the decline caused by SONG closure in 2012, nuclear generation is rather constant whereas hydro generation varies according to the water availability. Renewable generation increases over time to 27 (14) TWh of solar (wind) power in 2018. Since the introduction of emissions trading in 2013, gas-fired generation decreased by about 25% to 90.7 TWh in 2018.

Load shows a decreasing trend falling from about 300 TWh in 2012 and 2013 to about 285 TWh in 2018.

Figure 7: Generation mix



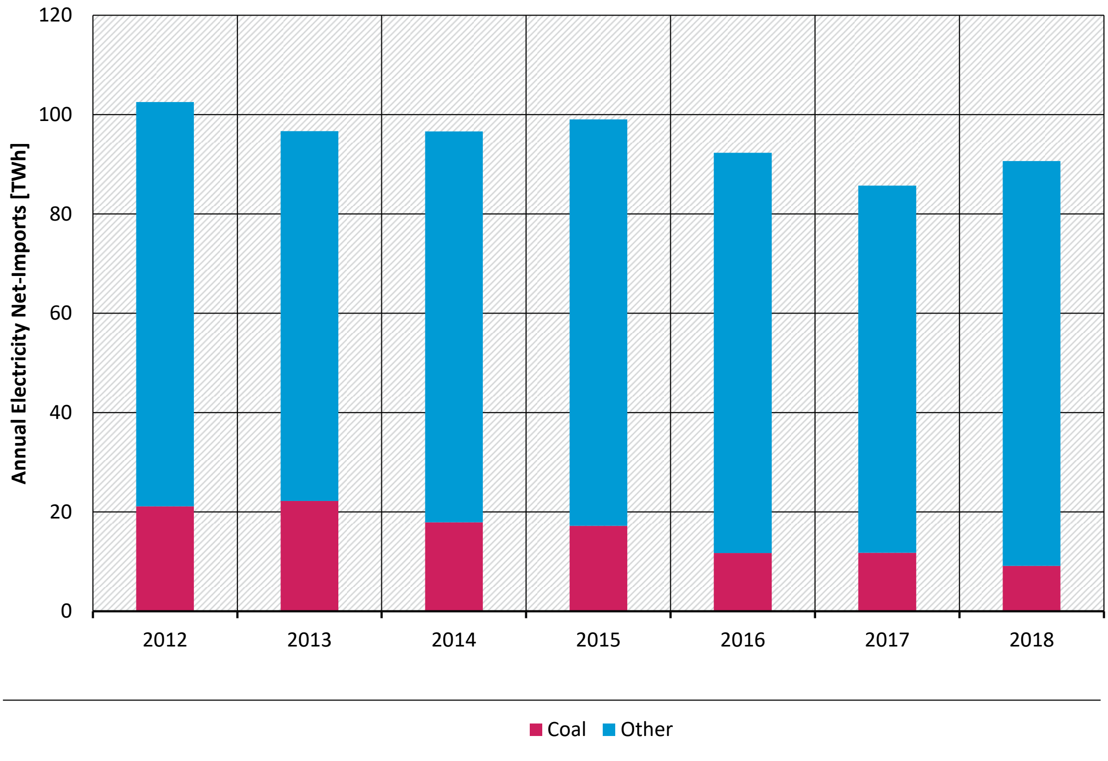
Source: Own depiction based on CA Energy Commission: https://ww2.energy.ca.gov/almanac/electricity_data/electricity_generation.html. Load is calculated as total in-state generation plus imports.

[43] Own calculations based on: http://www.ecdms.energy.ca.gov/

Cross-border electricity trade

As it can be seen, California relies on a high share of imported electricity. In fact, about 30% of electricity is imported. Figure 8 shows the development of California's electricity imports since 2012 differentiated by either coal-based or other generation. Overall, imports decreased over time. In 2012 and 2013, 20 TWh of imports relied on carbon intense coal generation. Coal-based imports decreased by about 55% to 9 TWh in 2018. This might be due to the introduction of emissions trading in 2013 that also applied to the carbon content of electricity imports and, thus, increased the price of coal-based electricity imports.

Figure 8: Annual Electricity Net-Imports



Source: Own depiction based on California Energy Commission: https://ww2.energy.ca.gov/almanac/electricity_data/electricity_generation.html.

4.2 Wholesale market and dispatch

The Californian electricity market is a centrally dispatched market with nodal pricing functioning in two market stages. First, a day-ahead market is cleared followed by the real-time market allowing for intra-day adjustments. Both markets are operated by the California Integrated System Operator (CAISO).

The day-ahead market opens 7 days before delivery time and closes at 10 am the day prior to delivery (see Figure 9; CAISO, 2020). All generation units connected to the CAISO electricity grid are required to participate in the day-ahead market. They submit complex bids containing not only several cost components but also must-run constraints (Burtraw et al., 2019). CAISO checks bids for market power. In case market power is detected, bids are revised to a pre-defined upper limit. After the revision of bids, CAISO solves for the least-cost dispatch taking into account constraints of the transmission grid. Prices are determined on a nodal level, i.e., one price for each node in the transmission grid. Results of the day-ahead market are published at 1 pm the day before delivery.

Figure 9: Timeline California electricity market

Source: Own depiction

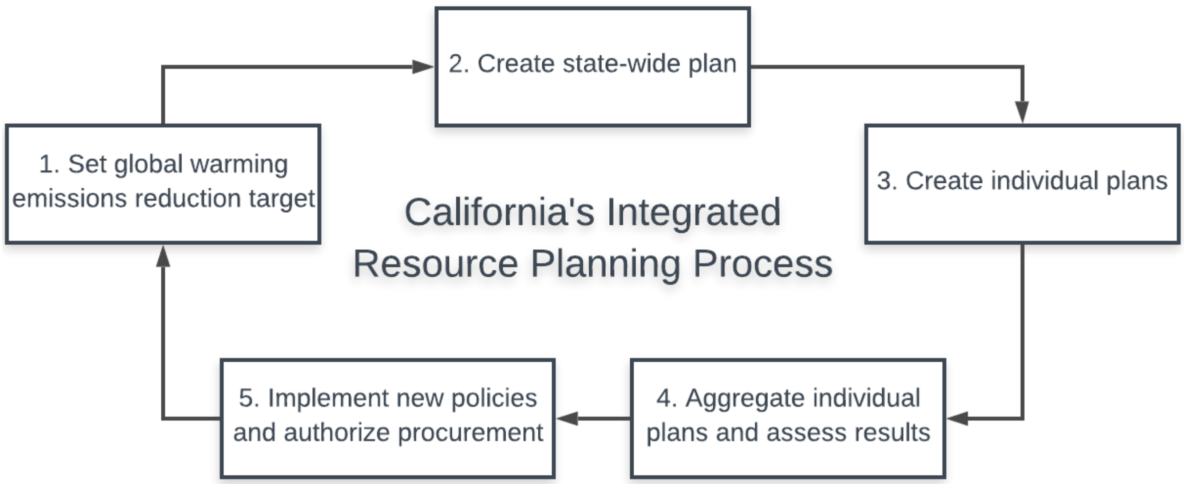
The real-time market opens at 1 pm the day before delivery and closes 75 minutes before delivery time.[44] Results of the real-time market are published 45 minutes before delivery time. These results constitute the final production schedule of power plants which dispatches power plants usually in 15- or 5-minute intervals.

Within the scheduling process, CAISO also optimizes the selection of power plants to provide ancillary services including spinning and non-spinning reserve as well as primary reserve for frequency control.

4.3 (Dis-)Investment and interacting policies

With the Clean Energy And Pollution Reduction Act (SB-350) of 2015, the CA government mandates an Integrated Resource Planning process (IRP). The IRP process regulates the long-term procurement of energy ensuring that climate and energy efficiency targets are met. The overall IRP process implemented by the California Public Utilities Commissions (CPUC) is repeated every two years (see Figure 10).

Figure 10: California's Integrated Resource Planning Process



Source: https://blog.ucsusa.org/mark-specht/integrated-resource-planning-california

Every two years CPUC creates a state-wide resource plan for the Californian electricity sector. Electricity providers also produce a plan how they will invest to fulfill their individual targets. Comparing its own and the aggregation of the providers' plans, CPUC evaluates the need for further policies and permits clean energy and energy efficiency investments.

[44] https://www.caiso.com/market/Pages/MarketProcesses.aspx

Provided the IRP process, investments in the Californian electricity sector are decentralized but characterized by 'strong regulatory oversight' (Burtraw et al. 2019). We next describe the different regulatory instruments used to ensure that the electricity sector meets its climate targets.

4.3.1 Promotion policies

- **Renewable energy promotion**
  California employs a Renewable Portfolio Standard (RPS) to promote generation based on renewable energies. The RPS requires utilities to produce or procure a certain percentage of their retail energy using renewable energy source. In California, most renewable sources such as wind, solar, and biomass qualify for support. Large hydro facilities are, however, excluded.[45] In 2011 the target was set to a share of 33% in the year 2020. In 2015, the target has been revised to 50% in 2030.[46] Besides the RPS, California also uses tax exemption (for solar) and feed-in-tariffs (biomass) to promote renewable production.
  Besides the direct support of electricity production from renewable sources, California also established indirect incentives in particular for households and small businesses. The Net Energy Metering program (NEM)[47] allows customers of the three large IOUs (PG&E, SCE, and SDG&E) to become prosumers, i.e., to become producers if generation exceeds own consumption and still be consumers in times of low production. The possibility to become producers implements additional incentives for the adoption of renewable energy technologies.
- **Combined heat and power (CHP) promotion**
  Under the Waste Heat and Carbon Emissions Reduction Act (Assembly Bill 1613), California establishes a feed-in scheme for CHP generation. The target is set to 4 GW of additional CHP capacity in 2020. The system promotes small-scale and newly build power plants with net electrical capacity below 20 MW and installed after 2007. To qualify for the CHP promotion scheme, power plants have to fulfill efficiency criteria in terms of heat and carbon efficiency: Heat-efficiency has to be above 62% and carbon emissions may not exceed 499 kg/MWh.[48]
- **Storage promotion**
  In 2010, Assembly Bill AB 2514 authorized CPUC to evaluate the need for storage facilities to reach California's emission and renewable targets as well as to optimize the electricity grid.[49] CPUC adopted mandates to procure energy storage for the three largest IOUs. The additional storage capacity allows a better integration of renewable energies, in particular, solar. Electricity peak demand occurs during evening hours whereas PV production peaks around noon. With the additional capacity it became easier to serve peak demand with renewable capacity. On the other side, however, increased storage capacity led to a flatter demand profile.

[45] See CA Energy Commission, 2017 for a more detailed description of the eligibility requirements
[46] For a detailed survey of the renewable energy policy in California, its current and past stage as well as impacts on the electricity market see Burtraw et al. 2019.
[47] https://www.cpuc.ca.gov/NEM/
[48] For a detailed description of the eligibility criteria including NO_x emission standards refer to CA Energy Commission (2015).
[49] See https://www.cpuc.ca.gov/General.aspx?id=3462 for a more detailed description.

4.3.2 Capacity markets

Under the Resource Adequacy legislation50 introduced in 2004, load serving entities (LSE) have to procure capacity in order to meet reliability criteria. Most importantly, LSE have to procure capacity to meet their peak demand including a reliability margin of 15% (CPUC, 2019a).[51] Qualifying capacity includes all kinds of technologies including CHP and non-dispatchable capacities such as wind and solar. These non-dispatchable technologies do not account with their full capacity but with a certain capacity factor (CPUC, 2017). This capacity mechanism introduced in 2004 is likely to have fostered the large investment into gas capacities observed since the year 2000 (Figure 5).

4.3.3 Emission Performance Standard (SB 1368)

The emissions performance standard (EPS, Senate Bill 1368)[52] limits utilities' long-term investments (i.e. new construction, new or renewal contracts of five years or more, and major investments in existing plants) for power plants based on greenhouse gas emissions. The EPS is a facility-based emissions standard. It requires power plants serving Californian consumers to have emissions no greater than a combined cycle gas turbine plant (1,100 pounds of CO2 per megawatt-hour).[53] All financial investments must meet the EPS and, thus, investments into coal-fired plants are ruled out.

4.3.4 Once-Through Cooling Phaseout

In 2010, California enacted a regulation for the phase-out of once-through cooling[54] technology.[55] It affected 19 coastal gas power plants (around 20.6 GW) that used marine water for cooling. Around 10.4 GW have been retired by 2019; the retirement of 6.3 GW of capacity is expected by 2020, and the remaining 3.8 GW are expected to retire by 2029.

4.4 Retail market

Final consumers' choice of the electricity retailer is limited. Most consumer have to stay with the local utility. Under the "direct access program"[56], consumers can apply for the freedom to purchase electricity from a competitive provider called an Electric Service Provider (ESP). Using a lottery system, the California Public Utility Commission (CPUC) randomly grants access to the freedom of choosing the electricity supplier. This limited access to the direct access explains the large retail market share of former incumbent companies (see Figure 6). Since 2009 consumer have, however, the possibility to use "Community Choice Aggregation" (CCA)[57] as alternative for retail services. CCA are non-profit organization that bundle the demand of several consumers and organize procurement for the aggregated demand (Burtraw et al., 2019). This option has increased in popularity since 2015 with the increasing adoption of rooftop solar PV bundled into

[50] www.cpuc.ca.gov/ra/
[51] For a detailed description of calculation procedures, see CPUC (2019b).
[52] https://www.energy.ca.gov/rules-and-regulations/energy-suppliers-reporting/emission-performance-standards-sb-1368
[53] https://www.cpuc.ca.gov/general.aspx?id=5927
[54] Once-through cooling systems use ocean water for the cooling process of thermal power plants. When the water from a once-through system returns to the original source, its temperatures are significantly hotter than the surrounding water, and thus severely harm the marine ecosystem (see e.g. http://large.stanford.edu/courses/2018/ph241/macfarlane1/)
[55] www.energy.ca.gov/sites/default/files/2019-12/once_through_cooling_ada.pdf
[56] www.cpuc.ca.gov/General.aspx?id=7881
[57] www.epa.gov/greenpower/community-choice-aggregation

the CCA. In 2017 the market share of CCAs was estimated to be about 25% with an increasing tendency. This implies a more and more competitive retail market (CPUC, 2017).

Retail prices are mostly volumetric tariffs with little or no fixed fees. Tariffs are designed as increasing block-tariffs. That is, prices are increasing in steps in the amount of consumed electricity for each household. Borenstein (2017) found that these increasing marginal electricity prices are one of the drivers of the large solar PV investment as these investments reduce the amount of electricity to be bought from the retailer and, thus, the tariff is reduced.

Regarding the CaT, an important feature of retail markets are the so-called "California Climate Credits". The CPUC requires investor-owned utilities to distribute their proceeds from the auction of free allocation (see Section 2.1.2 on consignment) as credits to residential customers, small businesses, industry, and for clean energy and energy efficiency programs.[58] Since 2014, auction proceeds for residential consumers are equally distributed among all consumers of each IOU. Thus, twice a year, residents receive credits on their electric and natural gas bills identified as the "California Climate Credit" (CARB 2019c). In 2013, these credits added up to around $60 to $320 per household in the case of electricity, and $20 to $30 in the case of natural gas - depending on the IOU.[59]

[58] www.cpuc.ca.gov/General.aspx?id=5932
[59] www.cpuc.ca.gov/climatecredit/

5 Assessing electricity markets and the ETS' impact on abatement

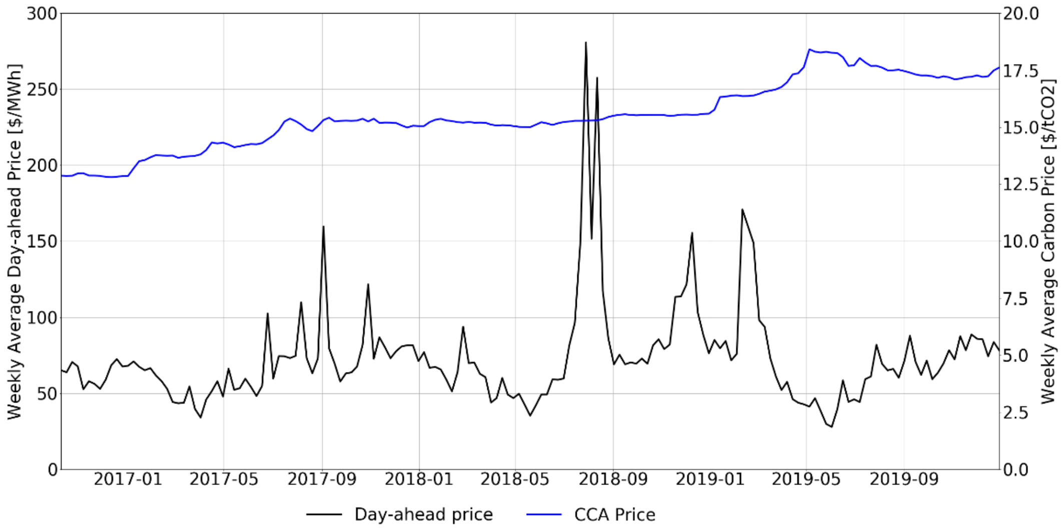
5.1 Pass-through of carbon cost to wholesale electricity market prices

The pass-through of carbon cost in electricity markets is an indicator whether generators pass-on carbon cost to the wholesale market price. This pass-through is the pre-condition that retail prices reflect carbon cost and, thus, are able to incentivize carbon abatement at the demand side.

5.1.1 Observations

Figure 11 shows weakly averages of the Californian day-ahead electricity prices together with the carbon price on the secondary market.[60] Visually the correlation between the two price series appears not be very large. In fact, the correlation coefficient appears to be about 1%.

Figure 11: Day-ahead electricity and carbon prices



Source: Own depiction based on California system operator CAISO for day-ahead and CCA price index (http://oasis.caiso.com/mrioasis/logon.do).

The low correlation of day-head and carbon prices is not necessarily an indicator for insufficient cost pass-through. Even if the pass-through is 100%, the correlation might be zero when the variation of other price components overlays the carbon price variation (see Section 3.1). Thus, we cannot conclude on the pass-through based on the correlation.

5.1.2 Impact of market structure and design

Carbon prices as a driver for day-ahead prices cannot be observed in the form of correlation. Nevertheless, our interview partners unanimously stated, that carbon price are fully passed to the wholesale market. We take this as an indicator, that no features in the Californian electricity market design preventing the pass-through. This result is not very surprising provided that California employs a centrally dispatched nodal market. As the independent system operator is responsible for dispatching carbon prices are take in into account when calculating cost for the least-cost dispatch.

[60] We use the SP15 load aggregation point as reference price. Using other nodes in the electricity grid does not change the figure.

5.2 Fuel switch: Impact of carbon price on dispatch

5.2.1 Observations

Already before the introduction of the CaT, the Californian electricity system only had a tiny share of coal generation. Therefore, there is nearly no potential to substitute coal by gas generation, i.e., the fuel-switching potential was and is zero. Consequently, we also do not observe fuel switching in the past. The role of carbon prices for the dispatch decision is only marginal.

In California, also electricity imports are covered by the ETS (see Section 2.2.1). Thus a "fuel switch in imports" would be possible. And indeed, we observe that coal imports to California have been decreasing between 2012 and 2018. This decrease might also be impacted by the introduced Emission Performance Standard (SB 1368), which requires all investments in baseload technologies to cover Californian electricity demand to meet a GHG performance standard – independent whether these facilities are located within or outside the state.

5.2.2 Impact of market structure and design

The impact of carbon prices on dispatch depend on various elements of the market structure and design:

- **Electricity mix:** The mix of installed capacity heavily impacts the fuel switch. The historically rather monolithic conventional capacity mix of only gas-fired plants naturally prevents short-term abatement in the form of fuel switching. This reduces the role of carbon prices for the dispatch decision.
- **Renewable energy support**: Renewable generation replaces conventional technologies as it is dispatched first leading to lower gas generation. Thus, renewable support decreases carbon-based generation and consequently reduces the impact of carbon prices on the dispatch.
- **CHP support**: Through the Integrated Resource Planning (IRP) process, CHP support is harmonized with the goal of carbon abatement by imposing efficiency requirements to be eligible for support. Nevertheless, CHP support is granted for gas-fired plants. Thus, the impact of the carbon price on CHP plants is lower compared to a situation without subsidies.
- **Capacity market**: The capacity market is technology neutral, i.e., also renewable technologies and CHP plants receive support. With this technology neutrality, it seems unlikely that the capacity market distorts the impact of carbon prices on the electricity market. In particular, adequacy planning remains under the IRP process.
- **Emissions Performance Standard:** In the longer-run, the Emissions Performance Standard reduces the carbon intensity of the capacity mix (see below) and, thus, also reduces the role of the carbon price for the dispatch decision.
- **Phase-out of once-through cooling:** In the longer-run, phase-out of the once-through cooling technology reduces the carbon intensity of the capacity mix (see below) and, thus, also reduces the role of the CCA price for the dispatch decision.

5.3 Impact of carbon price on low carbon investment/(dis)investment

5.3.1 Observations

As shown by Figure 5, we have observed large investments in natural gas and renewable capacity in the last decade.

5.3.2 Impact of market structure and design

Interview partners agree that these investements have not been induced by the CaT, but mainly by mandated programs. The following regulations are perceived to be the most important drivers of investment and disinvestment in California:

- **Capacity mix:** As conventional capacity are almost entirely gas-fired plants, the role of the carbon price for the dispatch decision is rather small (see above). On the reverse, as this implies no short-term abatement potential, the CCA price is likely to have a larger impact on investments, i.e., stimulating long-run abatement in the form of building new carbon-free capacities.
- **Renewable Energy Support:** Renewable Portfolio Standard, which requires a share of 33% of renewable energy generation by the year 2020. This policy incentivizes investements in renewable energy capacity. As part of investments are incentivized by the RES, the role of carbon prices for investment decisions is reduced.
- **Emissions Performance Standard:** The Emissions Performance Standard (SB 1368) requires investments in baseload generation to meet GHG standards. Thus, it implicitly prohibits investments in carbon-intensive technologies, and consequently favors low carbon investements. More specifically, emissions cannot be higher than in the case of an efficient combined cycle gas plant. As the performance standard already mandates low-carbon investments, the role of carbon prices for investment decisions is reduced.
- **Phase-out of once-through cooling:** Due to its harmful environmental impact, California enacted a regulation for the phase-out of the once-through cooling (OTC) technology. By the end of 2020, this will have led to the closure of around 17 GW of (mostly old) gas plants. This policy reduces the impact of carbon prices on divestures as these are already mandated by the policy.
- **Capacity markets:** Under the resource adequacy legislation load serving entities (LSE) have to procure capacity in order to meet reliability criteria. Although qualifying capacity also includes non-dispatchable capacities such as wind and solar, these technologies do not account with their full capacity but with a certain capacity factor. As the capacity market incentivizes investments, the role of carbon prices for investment decisison is expected to decrease.

Although interview partners agree, that the main investment incentives come from these policies, one expert stressed that the CaT and the other programs should be seen as complementary in how they shape expectation. He argues that even if we cannot measure a direct impact of the carbon price on investments, it probably affects investement decisions by shaping the expectations of investors.

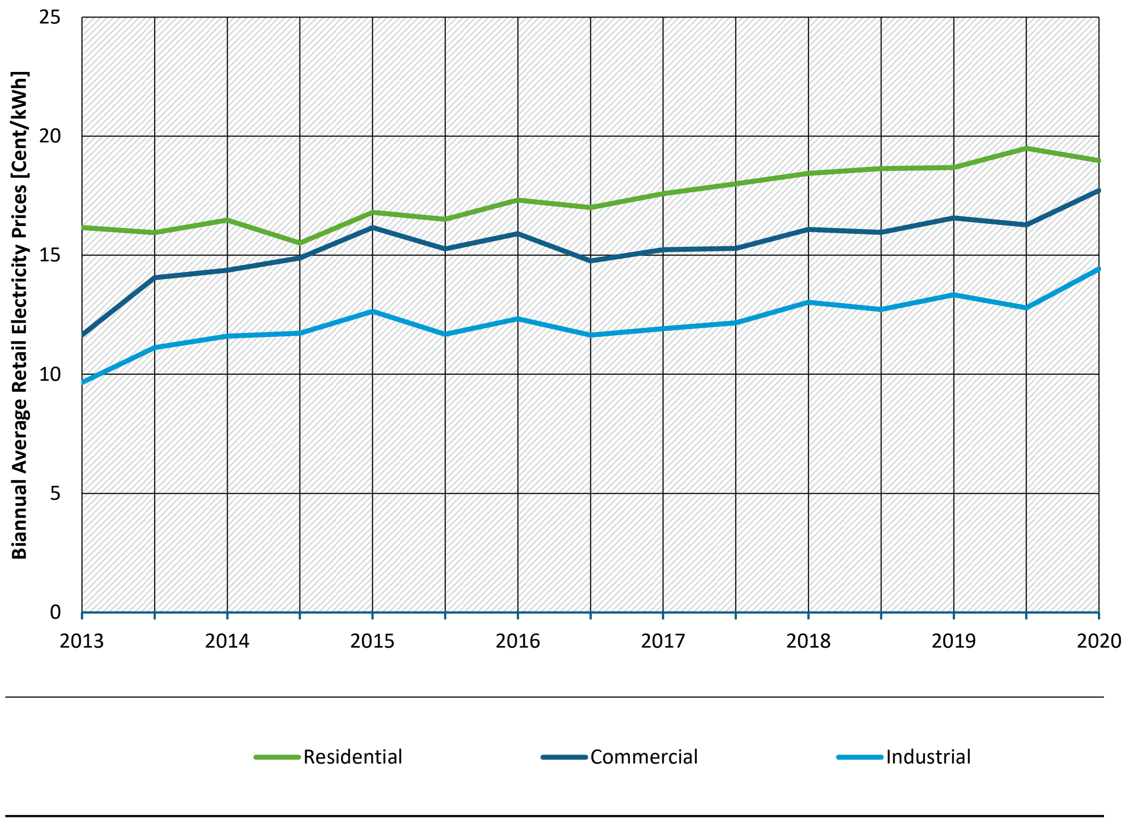
Finally, interview partners expect the CaT program to become more important in the future. Due to more stringent reduction targets (40% by 2030), some experts believe that it is likely that carbon pricing might become a driver of the transformation to a low carbon economy. CARB's Scoping Plan (CARB, 2017) estimates that slightly less than 40% of cumulative emission reductions between 2021 and 2030 will come from the CaT.

5.4 Demand reduction and pass-through of carbon cost to end consumer prices

5.4.1 Observations

As shown by Figure 7, electricity demand has slightly decreased over the past years. Figure 12 shows additionally the development of retail electricity prices since 2013 by end-consumer group. It becomes visible that retail prices increased since the introduction of the CaT. Whether the price increase is due to the allowances prices, cannot be shown. It is rather likely that also the renewable promotion scheme and its refinancing using retail price markups is an essential price driver.

Figure 12: Retail Electricity Prices



Source: Own depiction based on EIA data.[61]

61 www.eia.gov/electricity/data/browser/#/topic/7?agg=0,1&geo=000000000004&endsec=vg&linechart=~ELEC.PRICE.CA-RES.M~ELEC.PRICE.CA-COM.M~ELEC.PRICE.CA-IND.M~ELEC.PRICE.CA-TRA.M~ELEC.PRICE.CA-OTH.M&columnchart=ELEC.PRICE.CA-ALL.M&map=ELEC.PRICE.CA-ALL.M&freq=M&start=200101&end=202002&ctype=linechart&ltype=pin&rtype=s&pin=&rse=0&maptype=0

5.4.2 Impact of market structure and design

For carbon prices to induce demand reduction, there are two requirements. First, carbon cost need to be passed-through to end consumers. Second, consumers need to react to changes in electricity prices. Interview partners agreed that carbon cost are forwarded to end consumers by the utilities. However, due to low carbon prices, they believe that the impact on demand was very limited in the past. Nevertheless, two features should explicitly be highlighted:

- **Energy Efficiency Programs:** In recent years, California has implemented large energy efficiency programs (e.g. for LED lights, more efficient appliances, etc.). These programs are very likely to have induced demand reductions in the past. As from 2013-2017 about 0.5% of utilities' consignment returns were set aside for mandated clean energy and energy efficiency projects (CARB, 2019c). It is thus likely, that the CaT had an indirect impact on demand reduction. This indirect effect, is however, also likely to reduce demand in the permit market and therefore reduce the impact of the carbon price on final consumers. Through the programs, energy efficiency increases by adopting low-cost energy efficiency improvements. Thus, there is less room for energy efficiency investments triggered by carbon prices.
- **California Climate Credits:** Under the California Climate Credits program, residential customers, small businesses, and industry received about 82% of the proceeds that IOUs receive from selling their free emissions allowances at the auction. However, as these revenues are distributed on a per-household basis, i.e., in a lump-sum manner, it does not distort the cost pass-through of emissions cost to retail prices, and thus the carbon costs' incentive to reduce electricity demand. Yet, according to experts, the climate credits have a large positive impact on the household's approval of the CaT, and thus its political feasibility.

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