Incentivising Efficiency Optimization in the Canadian Aviation Industry Through Appropriate Emission Performance Standards

By: Matthew Teelucksingh, Samas Rehan
Group 28

Executive Summary

Despite being available to only the upper 20% of the global population, the aviation industry accounted for 3.5% of global GHG emissions in 2018. This industry is inherently energy intensive and also an essential means of transport and source of income to the global economy. These facts led us to think of ways we could regulate the performance of aircraft through the implementation of a performance standard which, upon validation, lead us to our research question: “What are the characteristics of a performance standard that would make it an effective tool for reducing emissions in the Canadian aviation industry without significantly impacting the industry's economic performance?”

Our data collection involved gathering literature relating to performance standards across different industries and identifying recurring characteristics through literature review. We performed screening on research articles and their sources by identifying keywords using a search engine - Connected Papers - and optimizing for relevance or interconnectedness of different articles. Subsequently we segregated the main types of performance standards from our funneled dataset, and prepared our dataset to fortify previously found characteristics and identify new ones through different case studies. Our content analysis followed the extraction of descriptions and characteristics, which were finalized through consensus amongst our group and diverse research papers pertaining to said standard. Our decision was based on the impact it had during its application, and its potential impacts on our research question. Following our content analysis we aggregated the impacts (positive and negative) to classify impacts as per their recurrence. Frequently recurring negative impacts would cause that characteristic to be excluded, while the popular positive impacts were included and formed the basis for our policy recommendations to provide a single-use efficient optimization of the Canadian Aviation industry in the short-to-medium term. From our aggregation of characteristics, exclusion of discouraging findings, and consensus, we identified numerous trends in the 17 performance standards that we aggregated. From these, the most prominent and recurring characteristics were:

1. Economic Flexibility
2. Technological Adoption
3. Competitive Response
4. Low-hanging fruit - stakeholder participation & dispersing targeted initiatives

We also revealed in our literature that the future of aviation decarbonization is quite bleak as conventional regulatory solutions have been thoroughly examined by policy makers and rejected due to the limited regulatory capacity they have on aviation due to the industry’s unique importance and economic characteristics. This bleak outlook limited the scope of our research to strictly the Canadian context in the short to medium term as we sought to recommend a performance standard to address Canadian specific regulatory inefficiencies.

In our proposed policy amendments, we advice decision-makers to analyze and potentially revise regulations around the aviation industry to remove existing barriers to decarbonization (implemented during the privatization of the industry) and introduce regulatory incentives to promote performance standards' implementations, generalize the key characteristics from successful policies and introduce legislation which promotes development of electrifying energy-intensive industries similar to - and including - the aviation industry (promoting research, educational programs, providing scholarships or grants to relevant field scholars, etc). In the process of crafting an effective performance standard we developed an interesting methodology for inductively creating effective regulations by looking at existing literature that we believe could have implications for policy research outside our research scope and as such, it should be examined as closely as our performance standard proposal.

Table of Contents

List of Figures

List of Tables

Introduction

In the fight for decarbonization in order to address issues of climate change, the aviation industry remains one of the most difficult sectors to comprehensively address. The issues that prevent emissions reduction in the industry primarily stem from the energy intensity that is inherent in operating commercial aircraft and their infrastructure (Ritchie, 2020). This is a largely technological issue and as such can most easily be addressed through innovation in low-emissions aviation technology. This dependence on technological innovation can have significant ramifications for climate change given the projected trends of the industry. In 2020 the global aviation industry was responsible for 2.5-3.5% of global greenhouse gas (GHG) emissions (Ritchie, 2020). While this is currently a minor percentage, the issue is that the aviation industry is one of the most GHG intensive industries in the world (Ritchie, 2020). Combine this with the fact that currently aviation is only available to 20% of the global population, and the potential for aviation to account for a significant portion of global emissions in the future becomes apparent (Ritchie, 2020). It is therefore important to determine the most appropriate methods of encouraging decarbonization within the industry.

To this end, the Canadian aviation industry provides an interesting case study into the issues with promoting decarbonization in the sector. The political and economic history of the industry has resulted in an economy and policy environment that is far more hostile to the aviation industry than the norm (Arnot, 2021). Consumer satisfaction, airline profit margins and average ticket prices all underperform relative to Canada's international standing (Arnot, 2021). This environment makes the industry especially resistant to regulations aimed at reducing emissions as they are uniquely sensitive to economic impacts. Our objectives reflect these limitations as we seek to determine the emissions reduction policy most likely to incentivise decarbonization without significant adverse economic impact. We believe that if a policy framework for encouraging decarbonization can be developed in such an adversarial environment, it would serve as an example for other frameworks seeking to decarbonize the aviation sector as the industry continues to expand into the future.

To that end we have identified emissions performance standards as our regulatory tool of choice as the literature indicates that the flexibility of a performance standard would allow us to achieve our objective: providing economic incentives for marginal improvements as opposed to large scale changes that could have serious economic ramifications in such a central industry. Based on the work of Rubin (2009) examining the impact of performance standards on energy markets and the work of Brown, et al. (2010) examining the impact of emission mandates on zero emission vehicle adoption it appears that

performance standards do show a level of success at reducing negative environmental outcomes without significant economic disruption. We believe this justifies our decision to focus on performance standards as the mechanisms for low-impact decarbonization. Work from Parry and Williams (1999) also informs the direction of our project and further research as they seem to indicate that performance standards can be a double-edged sword, with the characteristics of the standard drastically affecting how effective it is in incentivizing business decision making.

To this end, we have focused our research on determining what are the key characteristics of performance standards that would contribute to the standard being effective in incentivising decarbonization by the airline industry. We intend to address this research gap by performing document analysis on the descriptions and research of the most prominent performance standards that have been implemented and extract core overlapping characteristics that appear to contribute to the performance standard's success. While our overall objective is to create a performance standard that has the highest likelihood of encouraging decarbonization in the Canadian aviation industry while minimizing its economic impacts, our secondary objective is to explore the literature surrounding performance standards and their effectiveness and create a framework for determining what are the core characteristics of different types performance standards and regulatory instruments in general.

We believe that this is a relevant research aim as, as our literature review indicates, there are significant research gaps surrounding the implementation of performance standards in particular and how to determine the characteristics of an effective performance standard/regulatory instrument in general. We believe that seeking to construct a viable performance standard for decarbonization in the Canadian aviation industry will require us to develop the research methodology and framework to address some of these research gaps which would in turn make developing and implementing performance standards like these easier in the future as well as more effective in achieving their desired outcomes.

Literature Review

The main takeaway from our literature review was the existence of several gaps in the literature pertaining to our research objectives. As such conducting a comprehensive literature review on the impact of performance standards and the impacts of similar regulatory instruments on the aviation industry was more difficult than we anticipated. We believe that in order to gain the full context of our position there are two main areas of the literature that need to be explored: The development of performance standards and their impact on environmental policy making and the characteristics of the aviation industry and how it reacts to regulation.

Performance Standards and their Relevance Through Time

The discussion about performance standards and their place in the regulatory landscape has been an ongoing one in the literature. In the late 1990 and early 2000s static performance standards were the preferred regulatory instrument to deal with pressing environmental issues at the time such as road emissions and water quality. Zelenka et al. (1996) document the impact of US emissions performance standards on the development of gas and diesel engines in road vehicles. Through a technical analysis, Zelenka et al. does provide evidence that targeted emission standards, and enforcement through mandatory emissions testing, were a major driver of emission management technologies in conventional combustion engines. Subsequent research done by Knecht (2008) indicates that development in emission reduction technologies in gas and diesel engines are closely tied to the demands performance standards place on auto makers, making the claim that "Diesel engine development for use in light-, medium- and heavy-duty road vehicles is mainly driven by more and more stringent emission standards" (Knecht, 2008).

As concerns about climate change and the need to address GHG emissions grew in international importance a debate between two schools of regulatory thought emerged: those in favor of market based mechanisms and those in favor of more traditional forms of regulation. Many of the criticisms of performance standards' ability to encourage GHG emission reduction center around these measures being "static", requiring "inefficient centralized information collection and enforcement mechanisms" and being "inflexible in the face of exogenous change". These criticisms seem to be directly informed by an early influential work: The Handbook of Natural Resource and Energy Economics where, in Chapter 10, the authors perform an analysis of the characteristics of various types of policy solutions where they classify performance standards as being largely static instruments that do not dynamically respond to changes in the policy/economic environment (Bohm, Russell, 1985). There were attempts to address the issues with conventional performance standards as indicated by programs such as the United States EPA's EPA's Project XL which allowed firms to voluntarily set their own performance standards, provided it did not decrease environmental quality (Blackman, Boyd, 2000). These experiments were a mixed bag however, with success or failure largely being determined by specific characteristics of the markets where they were applied such as oligopoly status and heterogeneity of abatement costs (Blackman, Boyd, 2000). From this, their emerged a general consensus in the literature that static performance standards did have their use cases, but in many instances the flexibility of market based policies allowed them to achieve similar environmental targets in a more cost effective manner as they were more responsive to the heterogeneity of abatement costs and distributed these costs proportional to firm's relative efficiency (Newell, Stavins, 2003). This was especially true in the case of GHG emissions reduction.

Recently however, off the back of several successful implementations of environmental performance standards relating to the sale and distribution of Zero Emission Vehicles (ZEVs), literature has emerged indicating that performance standards can be a powerful tool in forwarding emissions reducing technology adoption without negative economic impacts. A paper by Sykes and Axsen (2017) though focused on the inability of ZEV mandates to generate spillover adoption in areas that do not have mandates of their own, demonstrates that a mandatory standard of electric vehicles is very effective in spurring EV adoption without an adverse economic impact in British Columbia. Evidence from the implementation of a ZEV mandate in California also indicates that standards provide a significant push factor over time, shifting to a more proactive stance towards zero emission technology despite continued negative reactions by their representative political coalitions (Wesseling et al., 2014). The conclusions drawn from Wesseling et al. (2014) are particularly relevant to our research as they provided recommendations on how performance standards can become more effective at encouraging technological adoption. They centered around: policy makers engaging with individual firms directly (as opposed to their political coalitions/representatives), negotiating preferential treatment for specific technologies to foster inter-industry competition and "technology-forcing" performance standards in conjunction with forms of positive incentivisation such as financial incentivization (Wesseling et al., 2014).
The empirical findings about the success of a "Demand-pull" performance standard strategy as Wesseling et al. (2014) calls it are given additional validity as they retroactively validate the findings of research done by Mohr (2006). He determined that environmental performance standards can in fact be effective at encouraging the adoption of technology (this was contrary to the prevailing academic sentiment at the time) while being flexible enough to avoid adverse economic impacts as long as they adhere to specific characteristics. These were: firms being heterogeneous in the technology's adoption costs, regulators engaging with individual firms frequently and the standard is combined with another regulatory instrument to increase flexibility (Mohr, 2006). The increase in ability for environmental performance standards to encourage technology adoption/development through increased flexibility is critical to our research as we move on to address a knowledge gap in performance standard research: environmental performance standards in the aviation industry and their projected impacts.

The Aviation Industry: Characteristics and Regulatory Challenges

The existing literature on GHG emissions in the aviation industry is grim. As already stated the industry accounts for between 2.5-3.5% of annual global GHG emissions (Ritchie, 2020). The issue, however, is not the current absolute number, it is the projected growth of the industry and subsequently its share of

global emissions. That annual emission range is for an industry utilized by only roughly the wealthiest 20% of the global population (Ritchie, 2020). It is no surprise that decarbonization of the aviation industry has been a topic of discussion in international climate change forums as well as academia. Unfortunately the conclusions drawn from subsequent research raise some serious issues, some that we hope to address with our research. The first issue raised is that by its nature the aviation industry is difficult to decarbonize. It is a very energy intensive industry that results in each user having a large carbon footprint (Ritchie, 2020). The demand for air travel has been found to be relatively inelastic as determined by a meta-analysis done by Brons et al. (2002). What this means for policy makers is that many of the popular market based mechanisms are not as effective in reducing emissions as, in the short-run airlines are simply able to pass the increased cost of operation on to the consumers, which would result in continued emission growth and decreased welfare for the consumers (Brons et al., 2002). The difficulty of regulating airlines due to the demand-side issue is displayed in an analysis of decarbonization pathways in key European countries done by Moberg et al. (2019). They found that currently GHG emission reduction has been centered around nudging at the individual level and that aviation emission reduction was primarily done through minimal economic instruments such as a passenger tax. They highlighted that the current consensus is that demand-side management of aviation emissions is not a policy priority as they will be ineffective due to the inelasticity of demand, which is fundamentally a result of a lack of alternatives for the services that airlines offer (Moberg et al., 2019). They conclude by stating that the only currently viable method of emission reduction would be artificial demand reduction (for example an individual carbon budget that only allows a few flights per year), a very politically unpopular proposal (Moberg et al., 2019).

The Moberg et al. (2019) paper highlights the primary reason for the industry's resistance to decarbonization - technology. With most emissions regulation, the stated objective is to reduce the specified emissions of an industry/sector. This can be done by reducing output or through reducing the per unit emission cost via technological innovation (Bows-Larkin, 2015). Most industries choose the latter, as they are able to innovate their way out of reducing output. In an article dedicated to evaluating policy solutions for decarbonization of the shipping and aviation sector Bows-Larkin (2015) concludes that emission gains from technological improvements have reached the point of diminishing returns and that any relevant technological developments would have to represent a large/fundamental shift in aviation technology that cannot be reliably predicted (such as a breakthrough in electric aircraft technology). He continues to reinforce the pessimistic perspective seen in Moberg et al. (2019) as he concludes that there are no viable short to medium term solutions decarbonization of the aviation industry and that policy makers have the expectation that "CO2 savings will generally be made in other sectors of the economy to enable aviation-related CO 2 to grow or be cut by less" (Bows-Karkin, 2015, p. 18).

Despite this dire conclusion Bows-Karkin (2015) does provide insights that are relevant to our region specific scope. While he does state that meaningful technological improvements are unrealistic in the short to medium term, he does claim that improvement in operations by reducing inefficiencies can result in significant emission reduction but the effort is a one-time event, as once efficiency is improved no more reduction can take place (Bows-Karkin, 2015). This is relevant for our scope as the literature on the economic and political climate of the Canadian aviation industry leads us to believe that such efficiency improvements have yet to take place and can be induced by the appropriate performance standard.

The Aviation Industry in the Canadian Context

The process of liberalization of the Canadian aviation industry is widely documented in the literature (Button, 1984). Deregulation of the airline industry in the US encouraged the Canadian government to begin the process of decoupling the airline industry from the government. This began in 1977 with the Air Canada Act that privatized the national flag carrier, turning it into a private corporation (Gillen, 1989). This, followed by changes made in 1994 and 1996 to privatize local airports and air traffic control respectively, left the canadian aviation market as a largely regional, privatized entity not unlike its US counterpart (Oum et al., 1991). Though it was conducted before the privatization of Canada's air traffic control service, Oum et al. (1991) provides a good account of the impacts of airline privatization on the industry, as well as the justification of said impacts. A lack of heavy competition from international players, monopolistic tendencies and imbalances of route volume early on, mainly concentrated in southern Ontario, resulted in an airline industry with higher fares, lower service quality and more inefficient relative to their US counterparts. Though this trend did reverse as liberalization continued and competition increased, the lack of government subsidization of airports resulted in higher landing fees that airlines, without significant competition, did not have to absorb and as such passed onto consumers (Oum, 1991). To this day, the conventional opinion of Canadians' is one of dissatisfaction at inflated prices which are due to many of the same issues of the 1990s: high landing fees for airlines passed onto consumers due to low competition (Loh, 2020). Addressing these issues represent a knowledge gap in the literature as there does not appear to be any research on the impacts that changing the ownership-lease structure of Canadian airports would have on ticket prices and industry dynamics. Relevant to our research question however, is the apparent inefficiency in airline operations prevalent in the industry brought on by a lack of competition. This would suggest that optimization/efficiency gains can result in a one time emissions reduction as proposed by Bows-Karkin (2015), provided that the proposed performance standard is structured in a way so as to not reduce economic performance. The structure of

this performance standard is the subject of our research and represents a knowledge gap in aviation research in the Canadian context that we seek to address.

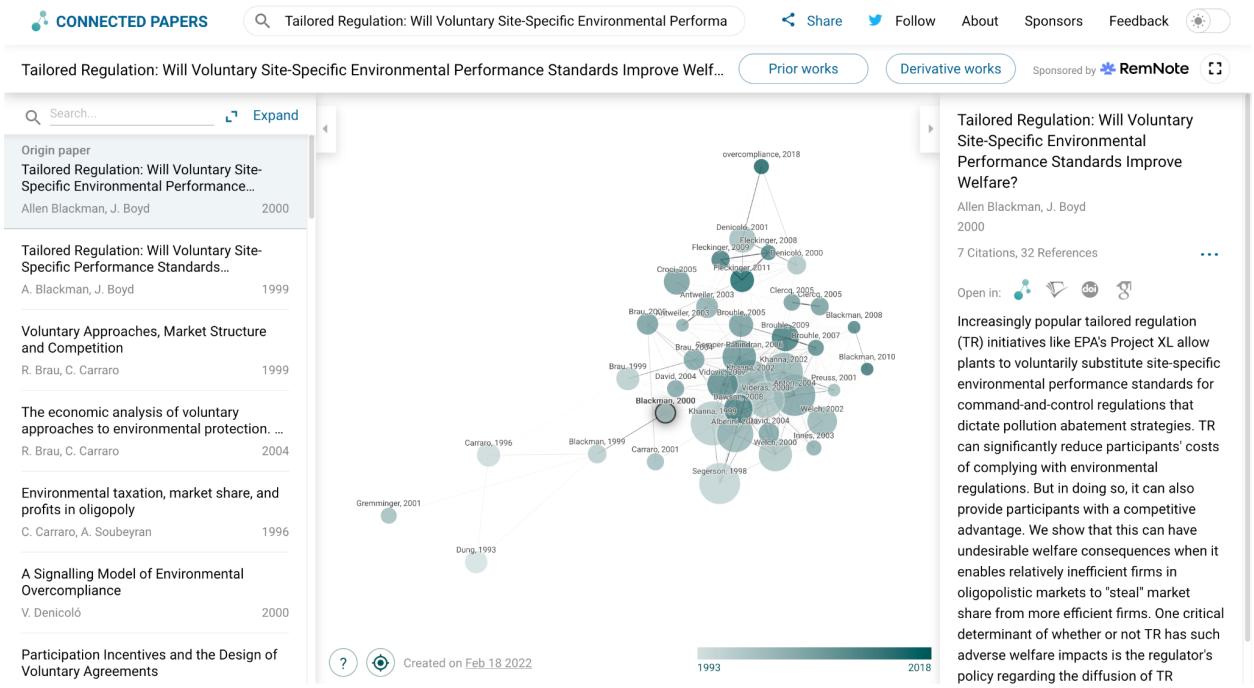
Research Methods

The main objective of our research process is to obtain recurring key characteristics of performance standards that we believe would be relevant for encouraging Canadian airline carriers to perform the efficiency optimizations necessary to reduce GHG emissions. We hope to extract these key characteristics by form of induction, which means ingesting relevant performance standard examples and correctly categorizing them. To do this we would need a set of criteria with which to narrow our scope. Fortunately in our review of the literature we came across several dimensions that were used to evaluate various policy instruments in The Handbook of Natural Resource and Energy Economics (Bohm, Russell, 1985). Some of Bohm and Russel's (1985) dimensions were static efficiency, centralized information requirements, enforceability, flexibility in the face of change and dynamic incentive effects (both push and pull factors). While not 100% applicable they do provide a good starting point with which to evaluate/score the standards we analyze. Our research process relies on a data-driven ingestion model where our conclusions are based exclusively on secondary sources such as: academic journals, government or non-government organization reports, books and policy documents. Our research methodology is also somewhat unique as much of our original dataset was extracted during our literature review during the process outlined below:

Step 1: Identify core academic literature discussing performance standards over time:

The first step was completed in our literature review. It involved determining which papers were the most relevant/central to the literature on performance standards. This can be done many different ways as relevance can be measured in number of views, citations, h-index value or other impact factors. For our project, we were primarily concerned with the interconnectedness or "centrality" of the journal articles. The original search was done through google scholar, sorted by "relevance" with keywords searched including: "performance standard", "emission standards", "performance standard environmental impact", "emissions standard analysis", "emissions standards market based", "environmental standard effectiveness" and "environmental standard impacts". Once the relevant articles were extracted from google scholar we filtered each paper through a service called "connected papers" that establishes the papers' connectivity within the body of similar literature. This gives us access to derivative works in order to expand our search if necessary.

Figure 1: The Connected Papers Graph for the Blackman, Boyd (2000) Tailored Regulation paper.



This step can be repeated as many times as necessary in order to build a large enough dataset. In many cases there may be very limited literature available on certain types of performance standards, or there may be an abundance of data. For our project we wanted to perform a relatively in-depth analysis of each of the performance standards mentioned so we did impose a limit on the number of standards we wanted to collect. It is important to remember that there is a trade off between the quantity of standards and the quality of each standard's analysis given a fixed amount of time.

Step 2: Extract performance standards from existing body of literature:

We now go through each paper and extract the specific performance standards mentioned. In most cases the standards that the paper is based on are listed in the Introduction or in the Methodology/Results section. In some cases a paper is based on a single standard, as was the case in our Blackman, Boyd (2000) Tailored Regulation example or the paper may reference several standards as part of a broader analysis. For example the report on Passenger vehicle Emission Standards by Sauer and An (2004) lists many different performance standards across various regions. It is here that our primary data filtering can begin.

Step 3: Perform content analysis on each performance standard in order to extract characteristics:

Now that we have our list of performance standards we must classify them according to the characteristics we outlined in Bohm and Russel's (1985) Handbook. We decided on a content analysis where we go through the descriptions and characteristics of each performance standard and classify a characteristic based on one or more Bohm and Russel (1985) categories. To do this requires an existing description of the performance standard. For some this is simple as the research paper associated with the standard provides an in-depth analysis and description. For example the Blackman, Boyd (2000) Tailored Regulation paper is about a single regulation and describes in detail the unique characteristics of said standard. This was the case for most of our performance standards, which greatly aided in our analysis. If detailed descriptions were not available then additional literature would have to be found such as government documents outlining the characteristics of the standard upon implementation.

We would classify these standards by describing a key characteristic, and then associating said characteristic with an increase along one or more Bohm and Russel (1985) dimensions. See the table below for an example:

Table 1: Showing a rough example of how characteristics are classified:

Blackman, Body (2000) Tailored Environmental Quality Standard		
Characteristic	Impact on Key Dimension	Justification
plants are allowed to develop pollution control strategies that "replace or modify specific regulatory requirements".	flexibility in the face of change	Allowing plants to develop their own strategies according to their individual needs allows the regulation to better accommodate a changing market landscape, increasing its flexibility.
Entirely Voluntary.	Difficult Enforceability	While a voluntary system does increase the flexibility in trades this flexibility for a low ability to enforce consistent standards across the entire industry.
For firms, the main attraction of TR is the significant cost savings that can arise from being allowed to circumvent inefficient command-and-control regulations.	centralized information requirements	Circumvents the need for centralized information requirements by shifting the onus of monitoring onto the firms. Again this would impact enforceability but does decrease the need for a central information aggregation

		mechanism.
Promote cost savings for individual firms with penalties if their custom strategy results in a reduction of environmental welfare.	dynamic incentive effects	Participants of the program are motivated by both a pull factor: a reduction of regulatory cost and overhead for designing a custom regulatory solution and a push factor: increased legal penalties if their solution reduces environmental welfare.

The table represents our data collection process for a single performance standard. We read the description of the standard and then, through consensus within our group, extract the unique characteristics of said standard - as represented by the first column in our example table. Next we extract the abstract feature the characteristic represents and determine (again through consensus) if the feature is positive or negative with respect to our overall objective "emission reduction within the aviation industry through performance standards that minimize economic impacts". For example, in our table the first key feature we extracted was "being flexible in the face of changing economic conditions". We determined that this feature would contribute positively towards our goal as we stated that we want to minimize the economic impacts to the aviation industry. Conversely the second characteristic we found, "difficult enforceability", we determined to negatively contribute towards our overall objective.

Step 4 Aggregate the positive and negative impacts on dimensions to determine most relevant key characteristics:

Finally, once step 3 has been done for every performance standard, we can aggregate the results and determine which Key Dimensions occur the most and which ones occur the least. Characteristics that positively affect the most prominent dimensions would be the characteristics that are most likely to result in positive outcomes for our proposed aviation emission performance standard and would be included. Characteristics that negatively affect the most prominent dimensions would either need to be excluded or actively disincentivized in our performance standard. The surviving characteristics are then modified in favor of the characteristics from performance standards from industries that share similar economic characteristics to the aviation industry such as large initial capital requirements, low levels of demand elasticity etc. It is important to note that other statistical tests are performed on the content analysis that informs our selection process such as the variation of key characteristics, and a random forest style of key dimension classification that will be discussed more in depth in the Discussion/Results section (eg: given that a standard already supports flexibility what is the likelihood that it will also support dynamic

incentive effects). Based on this regression analysis, characteristics with a higher correlation coefficient to positive outcomes of key dimensions will be prioritized over characteristics that do not.
Based on the confluence of qualitative described above, the aggregate results of this analysis are used to construct a policy recommendation for an emission performance standard that would incentivize a one-time efficiency-based optimization of the Canadian aviation industry in the short to medium term without significant adverse economic impacts.

Results and Discussion

We identified core academic literature that discussed performance standards by using research aggregation tools such as google scholar and connected papers. Once we collected a sufficient amount of performance standard research, we extracted said performance standards and determined the relevant policy characteristics from each standard via content analysis. These characteristics were then classified as positive or negative based on if they positively or negatively contributed to our proposed performance standard objectives. These results were then aggregated and generalized characteristics of performance standards were extracted as characteristics that were likely to address the specific issues within the Canadian Aviation industry if included in a performance standard.

By using the methods we described above we built a dataset of both implemented and proposed performance standards that spanned various industries, concentrated around air quality/emission standards for road vehicles, CO2 reduction standards for coal and fossil fuel based power plants and other industrial emissions standards. This is consistent with our understanding of the field as the bulk of the research surrounding performance standards and their efficacy compared with other regulatory instruments was developed due to the regulatory “waves” of amendments to the US Clean Air Act (Mohr, 2006). As regulations that govern pollution/emissions of vehicles and power generation in the US get updated via the Clean Air Act there is often heavy policy debate and research about the impacts and performance of existing regulation as well as how it would compare to future proposed solutions (Mohr, 2006).
Interestingly, through our literature review we came across several emissions based performance standards that had not been implemented but had only been proposed, which we also included in our main dataset (Rubin, 2009). Even though these were theoretical, we believe that they warranted inclusion into our dataset as they were extensively documented and their proposed strengths and weaknesses, as well as the justifications for both, were thoroughly modeled (Rubin, 2009).
Using this dataset, we were able to aggregate the key characteristics of 17 performance standards and based on the patterns we observed, we can describe some general trends and key characteristics that

would help us accomplish our goal of emission reduction in the aviation industry without significant economic impacts through our own performance standard recommendation.

Economic Flexibility

One of the most frequently recurring themes in the performance standards we analyzed was a means of adding flexibility to the performance standard, mainly towards the requirements of individual firms. Our analysis indicates that this characteristic appears to be binary. Either a standard provides no flexibility for the firms that it applies to, as was the case for many of the fuel economy and coal based power emission standards we looked at (Rubin, 2009), or they provide large amounts of flexibility in the form of an emissions trading system (Bohm, Russell, 1985). Incorporating emissions trading systems to increase the efficiency/flexibility of a performance standard appears to be a fairly recent development as traditionally performance standards were considered a static regulation that was often contrasted against more market oriented options such as cap-and-trade or credit systems (Bohm, Russell, 1985). Many of the more recently implemented standards we observed do include tools that increase the economic flexibility of firms in an attempt to reduce their economic impact on said firms. These measures appear in performance standards where the industry being regulated is: politically/economically crucial and produces a good that has a low elasticity of demand (Collantes, Sperling, 2008) (Wesseling et al., 2014). The prime example for this would be the Zero Emission Vehicle production mandates implemented by California in 1990 (Collantes, Sperling, 2008). It provides a decent parallel to the Canadian aviation industry as the Californian automotive industry shares several key characteristics with it such as its aforementioned low elasticity of demand and central economic importance (Collantes, Sperling, 2008). Based on the success of California's ZEV mandate, as well as the incorporation of trading system into proposed performance standards for coal power plant emissions management (Rubin, 2009) we are confident in recommending a credit based trading system, similar to the ZEV mandate, as a key characteristic for a Canadian Aviation emission based performance standard. Our research suggests that a credit based trading system would take advantage of the differences in marginal abatement costs curves between the major Canadian airlines and incentivise a move towards more efficient and less environmentally impactful operations at a lower economic cost. How airlines would move towards more efficient operations however, is the subject of our next main takeaway

Technological adoption

Another main takeaway from our research revolves around the efficacy of technology standards and how traditional performance standards impact technological adoption. Initially it appeared that adoption of

environmentally beneficial technology would naturally follow from the implementation of traditional performance standards as evidenced by various studies attempting to determine why the wave of performance standards enacted during the early 2000s failed to, and in many cases, disincentivized green tech adoption in the automotive industry (Mohr, 2006). These emission standards, combined with several other standards in our dataset, all share several characteristics that we now know disincentivise technology adoption. The conclusion that we drew from our analysis was that performance standards do not inherently encourage technological adoption unless it is built directly into the structure of the standard. Many of the proposed coal power plant emission standards that we looked at had several key characteristics that were explicitly designed to increase adoption of new GHG reducing technologies (Rubin, 2009). These included tax rebates for investments made into green technologies, credits equal to the increased risk to operations involved in adopting new technologies and even direct cash payments to firms that were able to meet performance standards in novel ways (Rubin, 2009). Many of the other performance standards we included had issues encouraging technological adoption. The main reason for this, described by Mohr (2006), is that even when measures are implemented to increase the economic flexibility of the standard such as a trading system, the adoption of novel technologies increases the risks and costs of operation in a manner that makes them unlikely to be chosen by firms as the means with which they reduce their emissions to meet standards (Mohr, 2006). This explains why addressing the commonly cited barrier to technological adoption - the strictness of standards does not appear to increase how effective it is in encouraging technological adoption. As our objective is to reduce emissions in the aviation industry without significant economic impact; technological innovation appears to be one of the main ways to achieve this. This is why, based on our research, we recommend that our Aviation performance standard contain tools designed to explicitly encourage technological adoption such as direct cash payments for creative usages of green tech, tax credits equal to the risk taken by firms in adopting new unproven technologies or requiring firms to adopt important abatement technologies.

Competitive Response

An underlying trend which was observed across reviewed articles was the rising competitive nature of primary players who stood to benefit from achieving the highest rating from the performance standard they were attempting to conform to. A prime example is the Golden Carrot Program - Super Efficient Refrigerator Program (SERP) (Eckert, 1995) - where manufacturers were bidding to earn the badge of SERP by designing and presenting an energy efficiency prototype which met stringent guidelines of energy efficiency and emissions reductions for refrigerators as well as achieved distinction from the competition. The results were the achievement of a renowned compliance badge, support from market players to increase market share, and financial incentives to promote mass production of the prototype. A

competition may be redundant, however, as associated incentives to conform to the highest performance standard can be an attractive achievement on its own - used to attract revenue-making opportunities. This competition platform provided fellow manufacturers valuable insights, networking opportunities as well as a desire to have a chance at the same benefits. Another example of an energy efficiency standard is LEEDS which has different conformity levels based on the operational efficiency of a building from the basic design level. Benefits to achieving the performance standards certification are tax incentives, inherent operational cost savings, ability to attract tenants, achieving ESG objectives, etc. (Gregus, N., 2022). Developing competition can be healthy - allows aircraft manufacturers to invest in their R&D departments, and allows carriers to learn best practices from competing airlines globally. These incentive structures, such as creating an independent ranking organization that airlines must compete in though our performance standard and then providing rewards for top performers has the potential to spur innovation in the space and as such, we recommend inclusion of a similar system into our proposed standard based on our research.

In summary of our results, adoption of performance standards can be challenging if the process requisites are demanding of the players who are facing these standards. They can discourage new entrants if they are too stringent, be repulsive to small sized carriers if they are financially overbearing and restrictive to oligopoly competition if the inability to compete using innovation, limited R&D investment and lighter labor workforce. Hence success stories are more visible among standards with a focus on improving and optimizing conventional processes, existing machinery, or replacement of outdated equipment. This is why, if our objective is to incentivize the reduction of emissions via efficiency and technology gains without significant economic impact then we recommend this be done thought a performance standard that: has economic flexibility in the form of an emissions credit trading system, provides financial incentives for green technology adoption and that stimulates competition within the industry via a certification/prize structure for emissions reduction. These are the three main characteristics that we deemed essential for our proposed performance standard based on our research.

Low Hanging Fruit

There were also several themes about successful performance standards that we came across in our research that were not as strong or compelling as our three main recommendations but relevant enough in constructing a successful performance standard that they warrant inclusion. The first theme was stakeholder engagement. A key failure point in many regulations, especially automotive emission standards, was their lack of direct engagement with stakeholders when crafting their performance standards. Examinations of standards that were successful versus standards that were often violated by firms found that flexibility was a key factor in determining compliance, but that flexibility was closely

tied to stakeholder participation (Wesseling et al., 2014) (Knecht, 2008) (Zelenka et al., 1996). As such we believe a relevant characteristic of an effective performance standard would be one that facilitated a healthy dialogue between all of the key industry stakeholders in order to arrive at its targets. Another low hanging fruit for performance standards would be ensuring that emissions reduction that is specified by a performance standard is diversified across a company's processes. In many cases companies were able to meet performance standards by electrifying or decarbonizing a very specific process or area of operation where the marginal cost of emissions reduction was very low (Rubin, 2009). While in the short term this is not an issue as emission reduction targets have been met, in the long term it can cause issues as the standard has not encouraged a deep decarbonization of industry which could disincentivise further progress as it has made increasing emissions reduction more expensive in the long run. This was most prevalent in our analysis of fossil fuel based energy generation performance standards, namely coal fired power plants (Rubin, 2009). While it may be a niche takeaway we believe it if it was not accounted for it could create issues in aviation decarbonization and as such we recommend that the performance standard encourage airlines to achieve emission reduction targets through decarbonization of various areas of operation and to avoid concentrating their decarbonization in a single sector.

Limitations:

Based on the above trends in existing and proposed performance standards there is an underlying risk of creating a bias if research is considered from a narrow perspective (Waggoner et al., 2016). Comparing and extrapolating data from various performance standards gives us the ability to formalize our interpretation and reach a consensus on what the researchers, stakeholders and industry experts idealize as their focus for achieving reduction targets. The implementation of performance standards requires participation from various organizations - and requires a collaborative action plan from governing authorities, key market stakeholders, energy suppliers, utility providers and fiscal policy analysts, to name a few. Researchers need to ensure size and diversity to remove the possibility of a narrow or one-sided consensus. Another limitation could be the difference in perspective and knowledge gap of a diverse stakeholder set. The data collected from a diverse sample through various research programs, and a uniform research focus, would bring lower chances of prejudiced interests when suggesting the implementation of specific characteristics such as the economic impacts of implementing an energy trading system for competing aircraft carriers (Şenbabaoğlu et al., 2016).

In our case, as opposed to fellow teams, our team comprised only 2 members. Although we implemented a check process to ensure our data was holistically segregated to accommodate differing views and

research patterns, a smaller group continues to pose a risk to the accuracy of observed trends and distinct characteristics from the researched sample standards implementations across differing industries. To curb associated errors, we singled out research articles with similar focus on the performance standards and used the closing remarks of the researchers to conduct a consensus survey of relevant documentation. This, combined with the fact that your qualitative textual analysis heavily relied on reading performance standard descriptions and then arriving at consensus about key characteristics, makes the fact that we only require consensus between our two members our main source of bias and a key limitation of our research to be addressed if our work were to be repeated.

Areas for Future Research: The Continued Utility of Our Analysis Outside of a Canadian Context

Here we outline the direction we believe future performance standard research will take and how it relates to the development of our research question. Given our qualitative analysis of the current status of the research, we believe that performance standards are becoming more modular regulatory instruments. The dichotomy between market and non-market regulatory instruments is blurring in a manner that allows performance standards to serve as a platform for multiple regulatory instruments as outlined in our main results section. We believe further research is needed into the efficacy of performance standards in encouraging technological adoption and how they can be modified to this end. A broader point, more connected to our specific research question, is the state of decarbonization research within the aviation industry. When we began this project a cursory analysis of the literature revealed some fundamental issues with decarbonization in the aviation industry. The physical reality of aviation: the high energy intensity, the large capital requirements and necessary regulatory barriers to entry that reduce competition and the high operating costs and low margins for airlines that make them inherently risk averse all contributed to a bleak outlook for decarbonization (Ritchie, 2020).

After conducting a review of the available regulatory instruments we believe that there is room for policy innovation and that said innovation can help, at the margins, to encourage better environmental performance - especially in Canada where the policy and economic environment has created artificial barriers to decarbonization that can be overcome via regulatory correction (Oum et al., 1991). For the aviation industry as a whole however, our literature review and analysis of proposed policy solutions has put us in line with Bows-Larkin (2015) where he claims that the outlook for aviation in the short to medium term is bleak with respect to decarbonization. He claims that due to the nature of the industry significant decarbonization can only come from long term technological breakthroughs such as

electrification (Bows-Larkin, 2015) and that in the short to mid term the only avenue for emissions reduction is through a reduction in demand which, he concedes is not likely due to the industry's inelasticity of demand and its projected growth into developing markets (Bows-Larkin, 2015). Given our research, we share in his analysis and seek to highlight the limitations of our research outside of the Canadian context. Our proposed performance standard is an example of a regulatory change that (we believe) would improve the environmental efficiency of the Canadian aviation industry, however this would only bring the industry inline with many developed countries, which are all facing the same bottleneck to decarbonation - a lack of massive innovation in the electric aviation space (Bows-Larkin, 2015).

The aviation industry faces many environmental issues that are not addressable by the research methods and proposals listed in this paper and as such, we must acknowledge the limitations of our policy focused approach going forward. We once again agree with Bows-Larkin (2014) when he concludes "the sector expects CO2 savings will generally be made in other sectors of the economy to enable aviation-related CO2 to grow or be cut by less" (Bows-Larkin, 2015, p. 697) and that the bottleneck to decarbonization in the aviation industry globally is not regulatory it is technological as "if there were mitigation options available to the air transport sector, its relatively simple institutional set-up, with its small number of manufacturers, fewer markets and actors, as well as a lower number of major national players, would make incentivizing change practical" (Bows-Larkin, 2014, p. 697).

Recommendations to Decision-Makers

Based on our analysis of the literature and existing performance standards, we make the following policy recommendations:

1) Policy makers in charge of Canadian federal aviation policy should conduct a review of existing Canadian aviation regulation to determine which specific policies are contributing to the lack of competitiveness and inefficiencies within the industry. Our literature indicates that the privatization of the aviation industry, specifically the way it was done, had significant downstream impacts on the way that the Canadian Aviation industry was structured (Button, 1989) and continues to contribute to the resistance the industry has today to decarbonization. The literature does indicate that some of the issues such as increased industry concentration and low margins can be addressed through regulatory reform - whether that is through repealing existing inefficient legislation or creating new regulatory incentives such as our proposed efficiency performance standard.

2) Policy researchers should continue to develop our proposed framework of using inductive processes to extract the key characteristics that make policies effective and generalizing these characteristics into a form that allows it to be included in new regulations or policies. Our framework of induction and character extraction should be further examined to see if its utility translates into other areas of policy research and if it does, if it can be used to generate viable policy solutions to other existing problems.
3) Policy makers in charge of Canadian federal aviation policy need to construct legislation that encourages the development of, what the literature indicates is, the only long term viable solution to emissions in the aviation industry - electrification (Bows-Larkin, 2014). Policy makers should be developing solutions that encourage the long term electrification of the aviation industry and be providing incentives for large industry players such as Air Canada or WestJet to invest in the decarbonization of their fleets through the use of technology. Research into these areas has been described in the literature as the most viable path towards decarbonization of the industry and as such, policy solutions that encourage such research, such as conditional research grants or technical achievement bounties, should be encouraged via federal aviation policy.

It is important to contextualize our recommendations within the literature that we reviewed as in a way it informed our recommendations more than our results. The state of research into decarbonization solutions reflects the conclusions of the Bows-Larkin (2014) paper and as such it is important to make recommendations under the assumption that, even if the Canada specific regulatory issues are addressed, the focus for policy makers needs to be on the long term electrification of Canadian fleets.

Conclusions

The aviation industry is an industry that is in desperate need of decarbonization. The characteristics of the industry make it almost seem perfectly built to resist decarbonization efforts. The physical realities of the energy intensity of flying, the large operating costs that result in low margins that make firms harshly sensitive to changes, the massive upfront costs which favor industry concentration/monopolization and the inelastic demand for the service which blunts traditional regulatory instruments' effectiveness. Combine this with the fact that flying is largely a tool of the globally wealthy and that the income of the average citizen is trending upward and what we are left with does not bode well for the future of climate action: a highly energy intensive industry, strongly resistant to decarbonization and with massive potential for growth. Fortunately in our report we were able to identify an aviation industry that bucked this trend. The Canadian aviation industry is widely considered less efficient and competitive than its North American counterparts due to both the downstream impacts of previous privatization efforts and current

regulatory inefficiencies. While this seems like a negative conclusion from our literature review, it provided us a unique opportunity to research potential regulatory solutions to a problem that is usually defined by its resistance to policy solutions.

Our research into the types of regulations that are deployed to reduce emissions and the impacts they have on the affected industries led us to propose an efficiency based performance standard that focused on emissions reduction at the margins to minimize the economic impacts. In effect we were taking advantage of a gap in efficiency greeted by the existing problems with the Canadian aviation industry. This focus on performance standards let us to develop an inductive framework for analyzing the efficacy of other performance standards and extracting the characteristics that made them effective. By using the current literature on emissions based performance standards we were able to determine that a successful standard needed to have three main characteristics: It needed to be flexible in its approach to compelling emissions reduction in firms, it needed to encourage competition between firms towards emissions reduction targets and it needed to explicitly encourage technological adoption. We used our framework to recommend policy makers take a look at reforming the aviation regulatory landscape with our proposed performance standard as a core piece of legislation. More importantly however, we recommended that policy makers and researchers develop and utilize our inductive framework to craft more effective and efficient legislation that is more in-line with their stated objectives. We believe that our framework can assist in such construction by inductively selecting the most appropriate characteristics as opposed to determining them from the ground up.

Finally, the diversity in our recommendations stems from the fact that we found our methodology and literature review of equal importance to our results. Our literature review described the context in which the aviation industry sits - a rather negative one with respect to decarbonization and the methodology we developed reflected this fact. We strongly favored an inductive approach as our literature review indicated that we needed to be as effect as possible in selecting the most effective legislation if we wanted to observe any legitimate impact on aviation emissions. Overall, while our policy recommendations are the focus of the paper, we believe that the methodology we proposed is equally as, and in may cases more, important as an area of policy research. For aviation however, if we were able to convey only one idea to the reader, it would be the dire situation aviation decarbonization is in. The recommendations for the project are aimed at reducing an artificial inefficiency in aviation emissions in Canada in the short term, but our conclusions about aviation emissions in general, are bleak and lean towards the very long term electrification of global fleets.

References

Arnot, M. (2021, March 11). Opinion: Canada's aviation industry needs a total overhaul, not just a bailout. *The Globe and Mail*. https://www.theglobeandmail.com/business/commentary/article-canadas-aviation-industry-needs-a-total-overhaul-not-just-a-bailout/

Blackman, A., & Boyd, J. (2000). *Tailored Regulation: Will Voluntary Site-Specific Environmental Performance Standards Improve Welfare?* (SSRN Scholarly Paper ID 249273). Social Science Research Network. https://doi.org/10.2139/ssrn.249273

Bohm, P., & Russell, C. S. (1985). Chapter 10 Comparative analysis of alternative policy instruments. In *Handbook of Natural Resource and Energy Economics* (Vol. 1, pp. 395–460). Elsevier. https://doi.org/10.1016/S1573-4439(85)80013-0

Bows-Larkin, A. (2015). All adrift: Aviation, shipping, and climate change policy. *Climate Policy*, *15*(6), 681–702. https://doi.org/10.1080/14693062.2014.965125

Bows-Larkin—2015—All adrift aviation, shipping, and climate change.pdf. (n.d.). Retrieved February 18, 2022, from https://www.tandfonline.com/doi/pdf/10.1080/14693062.2014.965125

Brons, M., Pels, E., Nijkamp, P., & Rietveld, P. (2002). Price elasticities of demand for passenger air travel: A meta-analysis. *Journal of Air Transport Management*, *8*(3), 165–175. https://doi.org/10.1016/S0969-6997(01)00050-3

Brown, S., Pyke, D., & Steenhof, P. (2010). Electric vehicles: The role and importance of standards in an emerging market. *Energy Policy*, *38*(7), 3797–3806. https://doi.org/10.1016/j.enpol.2010.02.059

Button, K. (1989). Liberalising the Canadian Scheduled Aviation Market. *Fiscal Studies*, *10*(4), 19–52.

Collantes, G., & Sperling, D. (2008). The origin of California's zero emission vehicle mandate. Transportation Research Part A: Policy and Practice, 42(10), 1302–1313. https://doi.org/10.1016/j.tra.2008.05.007

Eckert, J. B. (1995). The Super Efficient Refrigerator Program: Case Study of a Golden Carrot Program (No. NREL/TP-461-7281). National Renewable Energy Lab.(NREL), Golden, CO (United States). https://doi.org/10.2172/102319

Gillen, D. W., Oum, T. H., & Tretheway, M. W. (1989). Privatization of Air Canada: Why It Is Necessary in a Deregulated Environment. *Canadian Public Policy / Analyse de Politiques*, *15*(3), 285–299. https://doi.org/10.2307/3550825

Gregus, N. (2022, January 11). 6 Benefits of LEED Certification. *Energylink.* Retrieved from: https://goenergylink.com/blog/six-benefits-of-leed-certification/

Iris, Ç., & Lam, J. S. L. (2019). A review of energy efficiency in ports: Operational strategies, technologies and energy management systems. Renewable and Sustainable Energy Reviews, 112, 170-182. https://doi.org/10.1016/j.rser.2019.04.069

Kent, A., & Mercer, D. (2006). Australia's mandatory renewable energy target (MRET): an assessment. Energy Policy, 34(9), 1046-1062. https://doi.org/10.1016/j.enpol.2004.10.009

Knecht, W. (2008). Diesel engine development in view of reduced emission standards. *Energy*, *33*(2), 264–271. https://doi.org/10.1016/j.energy.2007.10.003

Loh, C. (2020, June 27). *The Hidden Reason Why Flying In Canada Is Expensive*. Simple Flying. https://simpleflying.com/the-hidden-reason-why-flying-in-canada-is-expensive/

Moberg, K. R., Aall, C., Dorner, F., Reimerson, E., Ceron, J.-P., Sköld, B., Sovacool, B. K., & Piana, V. (2019). Mobility, food and housing: Responsibility, individual consumption and demand-side policies in European deep decarbonisation pathways. *Energy Efficiency*, *12*(2), 497–519. https://doi.org/10.1007/s12053-018-9708-7

Mohr, R. D. (2006). Environmental performance standards and the adoption of technology. *Ecological Economics*, *58*(2), 238–248. https://doi.org/10.1016/j.ecolecon.2005.07.008

Newell, R. G., & Stavins, R. N. (2003). Cost Heterogeneity and the Potential Savings from Market-Based Policies. *Journal of Regulatory Economics*, *23*(1), 43–59. https://doi.org/10.1023/A:1021879330491

Oum, T. H., Stanbury, W. T., & Tretheway, M. W. (1991). Airline Deregulation in Canada and Its Economic Effects. *Transportation Journal*, *30*(4), 4–22.

Parry, I. W. H., & Williams, R. C. (1999). A second-best evaluation of eight policy instruments to reduce carbon emissions. *Resource and Energy Economics*, *21*(3), 347–373. https://doi.org/10.1016/S0928-7655(99)00008-1

Ritchie, H. (n.d.). *Climate change and flying: What share of global CO2 emissions come from aviation?* Our World in Data. Retrieved February 16, 2022, from https://ourworldindata.org/co2-emissions-from-aviation

Rubin, E. (2009, June 11). A Performance Standards Approach to Reducing CO2 Emissions from Electric Power Plants. *Center for Climate and Energy Solutions*.

https://www.c2es.org/document/a-performance-standards-approach-to-reducing-co2-emissions-from-electric-power-plants/

Şenbabaoğlu, Y., Michailidis, G., & Li, J. Z. (2014). Critical limitations of consensus clustering in class discovery. Scientific reports, 4(1), 1-13.

Sauer, A., & An, F. (2004, December 9). Comparison of Passenger Vehicle Fuel Economy and GHG Emission Standards Around the World. *Center for Climate and Energy Solutions*. https://www.c2es.org/document/comparison-of-passenger-vehicle-fuel-economy-and-ghg-emission-standards-around-the-world/

Sykes, M., & Axsen, J. (2017). No free ride to zero-emissions: Simulating a region's need to implement its own zero-emissions vehicle (ZEV) mandate to achieve 2050 GHG targets. *Energy Policy*, *110*, 447–460. https://doi.org/10.1016/j.enpol.2017.08.031

Wang, X., Feng, W., Cai, W., Ren, H., Ding, C., & Zhou, N. (2019). Do residential building energy efficiency standards reduce energy consumption in China?–A data-driven method to validate the actual performance of building energy efficiency standards. Energy Policy, 131, 82-98.https://doi.org/10.1016/j.enpol.2019.04.022

Waggoner, J., Carline, J. D., & Durning, S. J. (2016). Is there a consensus on consensus methodology? Descriptions and recommendations for future consensus research. Academic Medicine, 91(5), 663-668. https://doi.org/10.1097/ACM.0000000000001092

Wesseling, J. H., Farla, J. C. M., Sperling, D., & Hekkert, M. P. (2014). Car manufacturers' changing political strategies on the ZEV mandate. *Transportation Research Part D: Transport and Environment*, *33*, 196–209. https://doi.org/10.1016/j.trd.2014.06.006

Wu, J., Xu, Z., & Jiang, F. (2019). Analysis and development trends of Chinese energy efficiency standards for room air conditioners. Energy Policy, 125, 368-383. https://doi.org/10.1016/j.enpol.2018.10.038

Zelenka, P., Cartellieri, W., & Herzog, P. (1996). Worldwide diesel emission standards, current experiences and future needs. *Applied Catalysis B: Environmental*, *10*(1), 3–28. https://doi.org/10.1016/0926-3373(96)00021-5

Appendix

Table 1: Dataset of performance standards spanning various industries focussing on vehicle quality, CO2 emissions, and several industrial practices.

Performance Standard	Characteristic	Impact on Key Dimension	In-Text Citation
EPA's Project XL tailored regulation	plants are allowed to develop pollution control strategies that "replace or modify specific regulatory requirements".	Flexibility in the face of change	(Blackman & Boyd, 2002)
	Entirely Voluntary	Increases difficult of enforcement	
	For firms, the main attraction of TR is the significant cost savings that can arise from being allowed to circumvent inefficient command-and-control regulations.	centralized information requirements	
	Promote cost savings for individual firms with penalties if their custom strategy results in a reduction of environmental welfare.	dynamic incentive effects	
	The justification for the ability of a firm to set its own standards was that firms more efficient at abatement would be able to compensate for less environmentally efficient firms.	Dependent on the industry have firms with heterogeneous pollution abatement curves.	
Corporate Average Fuel Economy Standards	Specifying strict standards of the average fuel economy for all vehicles operating in the US. A broad standard for all manufacturers	Inflexible standard setting static limitations for performance of all firms.	(Mohr, 2006)
	A reduction mandate that is based off of non-tradable emission allotments	Provides no incentive to firms with different abatement cost curves to continue to reduce emissions	

	Low-level of industry consultation prior to the creation and implementation of the standards	Results in standards that set unrealistic or overly ambitious targets for firms	
	High level of industry consultation after standard implementation and approaching deadlines	Increases compliance and decreases industry resistance/backlash	
	Strict standards about emissions reduction but flexibility in how to achieve said reduction targets	Disincentives new technology adoption	
	Negative incentives (fines) that were lower than the economic impact of abatement for many firms	Making firms unwilling to reduce emissions and simply view the new regulations as a new cost of doing business	
	A flexibility in prosecution/willingness to extend and modify standards if firms are unwilling or unable to meet demands	Low enforceability makes implementing standards difficult.	
		Reduces the negative economic consequences for firms that have a low elasticity of demand.	
EPA Diesel Emissions Standards	Specifying strict standards of the average fuel economy for all vehicles operating in the US. A broad standard for all manufacturers	Inflexible standard setting static limitations for performance of all firms.	(Mohr, 2006)
	A reduction mandate that is based off of non-tradable emission allotments	Provides no incentive to firms with different abatement cost curves to continue to reduce emissions beyond mandate, effectively caping environmental gains	
	Low-level of industry consultation prior to the creation and implementation of the standards	Results in standards that set unrealistic or overly ambitious targets for firms	
	High level of industry consultation after standard implementation and approaching deadlines	Increases compliance and decreases industry resistance/backlash	
	Strict standards about emissions reduction but flexibility in how to achieve	Disincentives new technology adoption	

	said reduction targets		
	Negative incentives (fines) that were lower than the economic impact of abatement for many firms	Making firms unwilling to reduce emissions and simply view the new regulations as a new cost of doing business	
	A flexibility in prosecution/willingness to extend and modify standards if firms are unwilling or unable to meet demands	Low enforceability makes implementing standards difficult.	
		Reduces the negative economic consequences for firms that have a low elasticity of demand.	
California (CASB 1368) CO2 Standard	A reduction mandate that is based off of non-tradable emission allotments	Provides no incentive to firms with different abatement cost curves to continue to reduce emissions beyond mandate, effectively caping environmental gains	(Rubin, 2009)
	Provides economic incentives for emissions reduction technology investment through specific financing incentives and tax write offs	Provides an economic incentive for the development and adoption of new abatement technology	
	Only applies to new electricity generators built after 2006 supplying baseload power from in or out of state	Limited in scope to reduce industry and society wide economic impacts to only the necessary areas.	
Oregon (ORS 469.503 and OAR 345-024-0500)	A reduction mandate that allows firms to exceed emissions caps by paying a fee per ton of CO2 emitted with no penalty. Creating a de-facto carbon tax above the standard cap	Allows firms flexibility in reducing CO2 emissions, causing an overall efficiency gain if the industry's abatement cost curves are heterogeneous.	(Rubin, 2009)
	Limited to new power generating plants built after 2007	Limited in scope to reduce industry and society wide economic impacts to only the necessary areas.	
	Standards were generated through a dialogue between environmental stakeholders and industry firms and was iterated/revisited upon stakeholder requests	Ensures not only that the standards remain politically viable, but that the terms are not dictated by a sole stakeholder that would have disproportionate impacts on other stakeholders	

New Mexico (SB 994) CO2	A reduction mandate that is based off of non-tradable emission allotments	Provides no incentive to firms with different abatement cost curves to continue to reduce emissions beyond mandate, effectively caping environmental gains	(Rubin, 2009)
	Applies very specifically to firms that were built after 2017 or first movers that utilize new emission reduction technology that increase their operational risk	The hyper-specific scope explicitly seeks to lower the risk/barrier to entry for firms adopting beneficial technologies as well as limiting the society wide and economic impacts	
		Flexibility in the face of change	
	Allows for increased operational cost as a result of emissions technology adoption to be discounted through tax incentives and credits	A hyper specific objective that encourages emissions reduction by new power plants to be done vie technological adoption	
U.S. Climate Action Partnership Performance Standard	A standard that is implemented in "phases" with increasing requirements for each standard	Distributes the economic impact of the standard over time, giving firms ample opportunity to adopt standards with minimal economic disruption.	(Rubin, 2009)
		Staggering standard implementation into phases allows for a higher overall level of CO2 reduction compared to if the entire standard needed to be implemented at once	
	Recommended as a complementary policy accompanying a larger emissions trading policy but does not incorporate an industry specific trading standard	If larger emissions trading policy is not implemented alongside the lack of an emissions trading system could reduce the efficiency of the standard and harm less efficient firms despite the multi-phase standards	
	Provides direct cash payments as a reward for adopting technology and projects that that store CO2 if they are early adopters	Explicitly encourages not just the reduction of emissions thought technology adoption but provides additional incentives to be first movers with respect to technology development and adoption	

	While it does propose to make this standard complement a broader emissions trading system, the standard itself is an emission reduction scheme based off of non-tradable emission allotments	Provides no incentive to firms with different abatement cost curves to continue to reduce emissions beyond mandate, effectively caping environmental gains	
Waxman-Markey Discussion Draft, The American Clean Energy and Security Act	A standard that is implemented in "phases" with increasing requirements for each standard	Distributes the economic impact of the standard over time, giving firms ample opportunity to adopt standards with minimal economic disruption.	(Rubin, 2009)
	Only applies to power generation systems that were granted permits under existing regulations and that derive at least 30% of their heat input from coal.	The hyper-specific scope explicitly targets most relevant firms, making the standard more efficient at emissions reduction while limiting/minimizing the economic impact to these specific firms (though increasing the impact for these specific firms)	
	While it does propose to make this standard complement a broader emissions trading system, the standard itself is an emission reduction scheme based off of non-tradable emission allotments	Provides no incentive to firms with different abatement cost curves to continue to reduce emissions beyond mandate, effectively caping environmental gains	
Sanders-Boxer (S.309) CO2 Standard	Only applies to power generation systems that generate more than 25 MWe and derive >50% of their fuel from coal	The hyper-specific scope explicitly targets most relevant firms, making the standard more efficient at emissions reduction while limiting/minimizing the economic impact to these specific firms (though increasing the impact for these specific firms)	(Rubin, 2009)
	Provides a low-carbon credit trading program that allows firms that generate electricity from low carbon sources to sell these credits to other firms.	An emissions trading system allows firms with different abatement cost curves to reduce emissions at different levels in a manner that is more economically efficient compared to a static standard.	

Natural Resources Defense Council CO2 Standard	A phase in standard that applies to only newly constructed power plants	Prevents immediate economic impact by only impacting future expansion/development projects. This increases the political viability of the standard while allowing the economic impact to be discounted	(Rubin, 2009)
	Provides an emission trading system in addition to the performance standard	An emissions trading system allows firms with different abatement cost curves to reduce emissions at different levels in a manner that is more economically efficient compared to a static standard.	
Center for American Progress CO2 Standard	A phase in standard that applies to only newly constructed power plants	Prevents immediate economic impact by only impacting future expansion/development projects. This increases the political viability of the standard while allowing the economic impact to be discounted	(Rubin, 2009)
	The standard does not specify a reduction target, it mandates the implementation of carbon-capture and storage technology, independent of quantity of reduction.	The lack of emission reduction targets provides firms stability as they can accurately budget the fixed cost of a technology standard	
	Standard also implements a CO2 cap-and-trade system that decreases in efficacy over time.	A cap-and-trade trading system allows firms with different abatement cost curves to reduce emissions at different levels in a manner that is more economically efficient compared to a static standard.	
	A standard that is implemented in "phases" with increasing requirements for each standard	Distributes the economic impact of the standard over time, giving firms ample opportunity to adopt standards with minimal economic disruption.	
The 1990 California Zero Emission Vehicle (ZEV) rule	Manufacturers are required to produce a specific number of ZEVs that is derived from the total number of cars said manufacturer sells in California	Makes the economic impact to firms proportional to their economic footprint. This form of "impact discrimination" makes the performance standard more efficient	(Wesseling et al., 2014)

	Manufacturers gain credits based on the range of the ZEVs they produce. Any additional credits above their required amount can be traded or banked.	This credit trading allows firms with different abatement cost curves to reduce emissions at different levels in a manner that is more economically efficient compared to a static standard.	
Renewable Energy Target policy of Australia	Mandate for all businesses regardless of industry to strictly control their energy usage, use renewable sources, and buy and surrender energy certificates as per the regulation. Applicable to all industries	independent of industry	(Kent & Mercer, 2006)
	Mandatory. Required the coordination of Commonwealth, state and territory government bodies, energy supplying companies, energy consumer companies (Mostly Heavy consumers) and renewable energy suppliers.	Fortify national renewable targets and increasing conformity towards international energy reduction policies like Kyoto Protocol and UNFCCC	
	Policy was reviewed through an invitation for all members in academia, industry specialists, energy giants, and interested parties to review, implementing inter-policing within the framework.	Peers reviewed by multiple parties diminished knowledge gaps and covered multiple perspectives.	
	policy was implemented with a target increase in interim periods during 5 and 10-year review tenures to curb the problem of baselines in old generators.	Updates targets as per economic requirements, promotes continual efficiency measures to meet updated targets	
	implemented an energy trading system with strict requirements based on size and consumption of consumer groups. Strict penalties to discourage non-compliance.	"Use what is needed". Difficult to implement in aircraft operations since preparation for contingencies require aircrafts to store extra fuel and resources.	

Super Efficient Refrigerator Program (a golden carrot program), US	Recurring competition for manufacturers of refrigerators and freezer units (R/F) to design efficiently and improve design which could showcase tangible cutdowns in usage and emissions generation.	Focussed on manufacturers specific to be innovative in their approach and produce new products in the competition	(Eckert, 1995)
	A voluntary program.	Does not provide enough incentive for industry leaders with high market share to revenue ratio to participate	
	Design or process improvement must showcase tangible cutdowns	Allows players to focus on performance efficiency without distractions.	
	Stringent requirements to win competition, Winner takes all	Makes performance standard increasingly legitimate, provides assurance of strong efforts. Increased market share, performance standard conformity badge, financial incentive to mass-produce winning prototype are ample incentives. Runner-ups get recognition and new ideas	
	Collaborative opportunity with government bodies, competing businesses, key market players, utility agencies etc. to improve commercialization of new models, develop uniform specifications, provide monetary incentives	Communication allows fostering combined efforts for achieving same target, designing programs to increase market share, and a combined effort to encourage ecological practices from consumers	
	SERP combines existing emission reduction programs with development and commercialization of new prototypes, encouraging long term investment plans, rewarding returns for R&D capabilities	increases investment in R&D departments as standards is effectively a measure of performance of the R&D of models.	

Building Energy Efficiency Standards (BEES), China	Low implementation at the building construction stage on average.	Performance standard applied mostly at the operational capacity and does not have design requirements as a prerequisite.,	(Wang et al., 2019)
	Implementation simulation at the design level showcased exceedingly promising results, let down by real time results during ongoing operations.	Standards implementation must be derivative of expected targets, and set standards to accomodate for margin or errors or non-uniformity during operational capacity.	
	Case comparison of low performance versus high performance BEES standards were marginal increment in achieved results.	improvements in existing standards and introducing improved standards based on existing trends and capacities could be discouraging to businesses if the ROI to input ratio for conformity to newer standards are low.	
	factors such as household characteristics, appliances characteristics, were not considered under the performance standard for building operations were based on constant values of entities present throughout the building, although variable factors contribute towards the overall energy output	Implementation of route optimization, flying practices, in-air operations must be dynamic based on the payload, itineraries, and unexpected changes external factors like bad weather, emergency landing, flight turnaround due to malfunction, etc.	
	Construction quality could be a contributing factor to increasing the effectiveness of the implemented performance standards and mandating at the construction level could allow for greater results in usage metrics	Manufacturers and carriers need to work hand-in-hand to improve their business practices and utilize standard implementation throughout the lifecycle of the product and processes	
Energy efficiency in ports: Operational strategies, technologies and energy management systems (a study of	Characteristics include efficiency in port operations, peak shavings, electrification of obsolete mechanisms, energy	Aviation industry's energy performance is also reliant on the operation of airports, hangars and docks and results can be extrapolated to optimizing energy	(Iris & Lam, 2019)

greenflag incentive program in Taiwan Kaohsiung port)	storage systems, cold ironing, etc.	usage in airports	
	Process flows for energy input, distribution, and saving of residual energy post operation.	Airports with and without night curfew policies in place can use process flows to manage the energy they use and distribute it according to requirements based on energy usage stats	
	Peak shavings based on peak operational capacities and offtime operations to manage constant fluctuations in energy which often results in higher power draw to accommodate sudden surges in energy demand.	Although many airports that function round the clock do not necessarily have a energy fluctuation, the amount of people within the facility during peak hours and offtimes can reduce the energy draw by HVAC, lighting, and significantly reduce the power draw by smaller regional airports	
	Energy management systems for appliances, vehicles, etc.	service fleets' energy consumption can be managed through energy management systems	
Season energy efficiency Ratio (SEER) and heating seasonal performance Factor (HSPF) Room air conditioner Standards in China,	Standard established since ACs large energy consumers in China owing to its population.	Aviation is a global industry and accessible and available for leisure & commercial use to the majority.	(Wu et al., 2019)
	Parameters and calculations are constantly compared and inter derived from standards of America, EU, Japan, and ISO.	Discord in the variety of performance standards for every country can be difficult to implement for a globally interconnected industry such as aviation.	
	Chinese RAC performance standard parameters are based on the population, climate zones, and calculated using relevant measures based on the computable parameters in China. Differing parameters and calculations across different countries.	Could lead to non-uniform performance standards for different regions, with a centrally implemented standard similar to ISO. Could bring up complications.	