# APPENDIX E

# STAFF REPORT: INITIAL STATEMENT OF REASONS

## Proposed Amendments to the California Cap on Greenhouse Gas Emissions and Market-Based Compliance Mechanisms Regulation

## Emissions Leakage Analysis

**State of California**

**AIR RESOURCES BOARD**

**Release Date: August 2, 2016**

## APPENDIX E:

## Emissions Leakage Analysis

In 2011 and 2012, Board Resolutions 11-32 and 12-33 directed staff to investigate potential improvements to industrial allowance allocation to better meet the Assembly Bill 32 (AB 32) objective to minimize emissions leakage to the extent feasible.[1] In response, ARB commissioned three emissions leakage potential studies to inform the development of assistance factors (AFs) for allowance allocation to manufacturing sectors. Based on these leakage studies, ARB staff has developed a revised methodology by which emissions leakage could be assessed, and revised AFs could be developed for application. A qualitative description of the development of this revised methodology, and the method by which revised AFs could be formulated, is provided in this appendix.

In commissioning the three studies, staff had intended to develop a revised methodology by which revised AFs, not including transition assistance, could be calculated and applied in the third compliance period (2018-2020). These revised AFs would be at sector-specific levels necessary to minimize potential emissions leakage. After additional thought and discussion with stakeholders, staff decided to extend transition assistance through the third compliance period, at levels set in the 2013 regulatory amendments. Any revised AFs that may be proposed as part of 15-day comment period would be implemented starting in the fourth compliance period (post-2020).

### A. Overview of Emissions Leakage Prevention Methodology

#### 1. Assistance Factors for Leakage Prevention and Transition Assistance

ARB freely allocates a significant quantity of the allowances necessary for entities in the industrial sector to comply with the Cap-and-Trade Program (Program). In the first three compliance periods of the Program (2013-2014, 2015-2017, and 2018-2020), this allocation is meant to minimize potential industrial emissions leakage, as directed by AB 32, and to help entities transition to an economy that includes a carbon price.

Emissions leakage occurs when a Program-caused decrease in emissions in California is compensated by a corresponding Program-caused increase in out-of-State emissions. The Program-caused increase in out-of-State emissions is a necessary condition for emissions leakage. A drop in California emissions and/or economic activity alone is not a sufficient condition for, nor sufficient evidence of, emissions leakage.

[1] California Health and Safety Code Section 38562(b)(8)

ARB currently minimizes potential emissions leakage by freely allocating allowances to covered industrial entities; for the majority of industrial sectors, this allocation is calculated in proportion to in-State production. Industrial allowance allocation is calculated using either an energy-based or product-based approach. Under both approaches, the current AF,[2] which ranges between zero and 100 percent, is the variable in the allocation calculation that determines the level of leakage protection and transition assistance provided to each sector. This rewards keeping output-driven emissions in the State by providing more free allowances as production levels increase. Through this free allocation, entities with high levels of in-State production (and emissions) receive larger quantities of free allowances than entities with low in-State production (and emissions). By scaling allowance allocation with output, entities with output-caused emissions are incentivized to remain within the State, and potential emissions leakage is minimized. Each industrial sector has an appropriate AF value that will prevent emissions leakage. An AF above that appropriate value yields allowance allocation in excess of that needed to prevent potential emissions leakage, and that excess portion of the allocation is provided for transition assistance.

In the original Regulation adopted in 2011, ARB staff set AFs equal to 100 percent for all covered industrial entities to prevent potential emissions leakage and also to provide transition assistance. In the leakage assessments for that rulemaking, industrial sectors were classified into three categories of leakage risk (low, medium, and high), and AFs for medium and low leakage risk sectors were initially slated to decrease starting in the second compliance period (2015-2017). The Regulation was later amended to delay this scheduled decrease until the third compliance period (2018-2020). This extended the 100 percent AF values (and transition assistance for medium-and low-risk sectors) through 2017 for all industrial sectors. No changes are proposed to the existing Regulation for the third compliance period (2018-2020); sectors currently designated pursuant to the initial leakage risk assessment as medium or low leakage risk will have AFs reduced to 75 percent and 50 percent, respectively, starting in 2018. Starting in the fourth compliance period, the revised methodology would replace these broad categories with industry-specific revised AFs at levels necessary to prevent potential emissions leakage.

This appendix provides details on how ARB could modify its determination of the allowance allocation levels that are needed to minimize potential emissions leakage for each industrial sector in the fourth compliance period, based on the revised methodology. The new level of allowance allocation for post-2020 compliance periods' allocation would remove the "transition assistance" portion of allocation but retain the portion of the allocation necessary to prevent emission leakage. At the outset of the Program, staff asserted that the level of transition assistance should decline over time, leaving continued free allowance allocation in future years at levels necessary to minimize potential emissions leakage (ARB 2010). The aforementioned Board

[2] AFs are assigned at the North American Industry Classification System (NAICS) six-digit sector level and by industrial activity (see "a" in Table 8-1 of the Regulation). For example, two industrial entities that both produce cement (NAICS 327310) would have the same NAICS 327310 AF assigned for the purposes of calculating industrial allowance allocation.

resolutions in 2011 and 2012, and the regulatory amendments process initiated in 2013, provided sufficient notice to industrial entities that assistance factors would be reevaluated by the third or fourth compliance period. Staff believes that the first three compliance periods provide a more-than sufficient period over which to provide assistance to help industrial sectors and the economy adjust to a carbon price, and that continuing to allocate in excess of amounts needed to minimize emissions leakage can result in windfall profits to industry and unnecessary costs to California consumers (Bovenberg and Goulder 2001; Bernard et al. 2007; Bushnell and Humber 2015).

## 2. 2016 Leakage Studies and Revised Leakage Metrics

### *a. Metrics Overview*

ARB commissioned three leakage studies specifically to evaluate and potentially modify AFs for all industrial sectors. Emissions leakage can occur to other countries (international leakage) or to other states within the U.S. (domestic leakage). One broad-sector study (Fowlie *et al*. 2016) analyzed international emissions leakage to other nations, and a second broad-sector study (Gray *et al*. 2016) analyzed leakage of California emissions to other U.S. states. These two studies complement each other to provide a complete picture of emissions leakage potential for most manufacturing sectors. The third study (Hamilton *et al.* 2016) was a stand-alone leakage analysis for four food processing sectors. These three studies are included in Appendix F. The studies have allowed staff to develop the revised methodology by which revised AFs could be developed and applied. This revised methodology would arrive at sector-specific revised AFs to minimize potential emissions leakage.

This revised emissions leakage risk methodology arrives at AFs through the calculation of two revised leakage metrics based on the studies' findings: the first metric would minimize potential international emissions leakage and the second would minimize potential domestic emissions leakage. These metrics would be additive assistance factor components. In other words, the international and domestic assistance factor components would be added together to yield a complete calculation of overall leakage risk for each sector.

Potential international emissions leakage would be identified and minimized by quantifying international market transfer (IMT), a metric developed by Fowlie *et al*. (2016) in the international study. IMT is the fraction of every dollar decrease in domestic value added in response to a carbon price that is offset by an increase in international production (i.e., IMT measures production leakage). Value added is an approximation of profit; it equals total revenues minus expenses for the sector. The IMT fraction would be one-for-one translated into the international portion of the revised AFs for each sector.

The second leakage metric is domestic drop (DD). DD is the projected decrease in California-specific economic activity in response to a $24.88 marginal compliance cost per $MTCO_2e$. This marginal compliance cost represents the 2030 Auction Reserve

Price assuming a 7 percent annual increase from the 2016 Auction Reserve Price, is 195 percent of the current allowance value, and is consistent with the value used in the economic analysis and Standardized Regulatory Impact Assessment. DD values are typically negative, indicating that increasing energy costs decrease economic activity. For the purposes of measuring DD, economic activity would be calculated in two ways. First, DD would be calculated based on the change in value added in response to a carbon compliance obligation. Second, DD would be calculated based on the change in output, an approximation of gross revenues, in response to a carbon compliance obligation. The domestic study developed DD estimates for each sector in response to an increase in energy prices equivalent to a $24.88 marginal compliance cost. These DD estimates are calculated without assistance (i.e., calculated at the full $24.88 cost) as well as net of different levels of allowance allocation that offsets a portion of this price increase (e.g., $12.44 representing 50 percent allocation). Value added DD estimates can be found in Table A1 of Gray *et al*. (2016), and are reproduced as Table E-1. Equivalent estimates for output DD have become available to staff after the workshop, and are included in this appendix as Table E-2. To minimize potential domestic emissions leakage, staff would set the domestic component of the revised AF for each sector at the level needed to prevent a fixed level of decrease in each sector's economic activity (hereafter the cutoff domestic drop, or cutoff DD) at the $24.88 marginal compliance cost per $MTCO_2e$. The cutoff DD is dependent on the $24.88 marginal compliance cost per $MTCO_2e$. A lower marginal compliance cost per $MTCO_2e$ results in a smaller drop in economic activity for each industry's given domestic AF component. By defining economic activity in terms of value added and output, the DD methodology ensures the domestic component of the revised AF is sufficient to prevent the cutoff DD not only in value added, but also in output.

Under the revised methodology, the international assistance factor component (equal to IMT) would be added to the domestic assistance factor component (based on the DD) to calculate the total revised AF for use in industrial allowance allocation calculations. To the extent that a sector is especially at risk of potential international leakage, the sector would have a large measured IMT, and consequently the international AF component would be large. To the extent that a sector is especially at risk of potential domestic leakage, its DD would be large (negative) and consequently its domestic AF component would be large. Figure E-1 provides a conceptual image of one sector-specific revised AF.

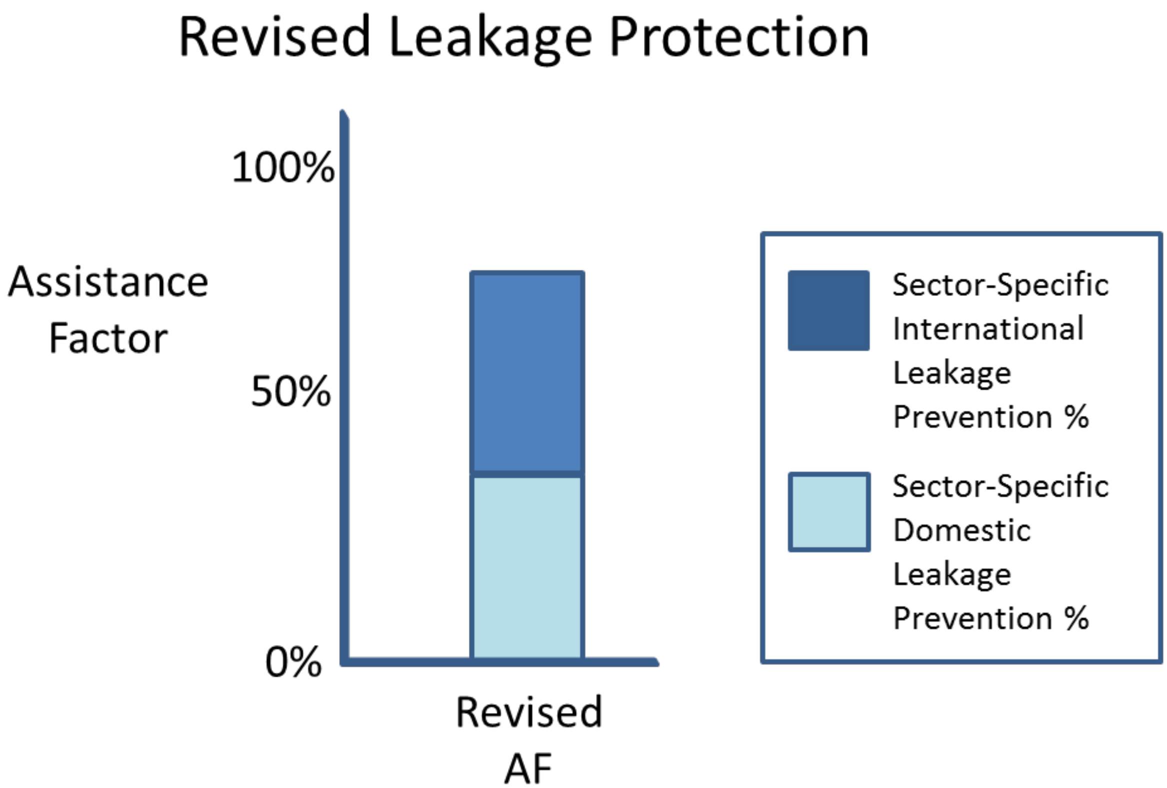


**Figure E-1. Schematic of sector-specific international and domestic assistance factors resulting in total revised AF.**

b. *Leakage Metrics Development and Assistance Factor Implementation Would Err on the Side of Caution*

Each of the three studies makes conservative assumptions that result in leakage risk assessments at the upper bound of the manufacturing sector's potential emissions leakage risk levels. In utilizing the results of the studies, staff's revised methodology would also use a conservative approach to translate the study findings into revised AFs. Staff believes that after the application of this conservative approach, the measured potential emissions leakage risk levels would be at the maximum possible potential emissions leakage risk for each sector, and the revised AFs would likely provide allowance allocation in excess of the amount needed to prevent potential emissions leakage for all sectors.

The international study is cautious in its assumption of the level of leakage implied by decreased exports and increased imports. The study assumes that every unit of decreased export from California is made up by a one-for-one increase in foreign production; in other words, the study assumes that there is no reduction in international consumption in response to a decrease in California exports. In reality, international competitors may not increase production to meet all of the international demand no longer met by California's producers. Conversely, an increase in imports may decrease foreign production directed to serve international demand rather than one-for-one increase foreign production. In both cases, the AF necessary to prevent potential international emissions leakage is less than the international AF components that would be proposed under the revised methodology.

The domestic study is conservative for two primary reasons: the assumed marginal compliance cost and the timeframe with which the study measured firms' adaptions to a carbon price signal. The domestic study assumes a marginal compliance cost that is almost twice the 2016 Auction Reserve Price; this high compliance cost assumption creates significant built-in conservatism in the revised AFs. The domestic study estimates short-term impacts of a carbon signal that are generally ten times the magnitude of the long-term impacts. ARB staff would use the short-term estimates upon potential implementation of the revised methodology, resulting in a larger domestic AF component for all sectors and a higher total revised AF.

Beyond these conservative assumptions in the studies, staff proposes additional levels of caution in establishing revised AFs for each sector. Additional IMT and DD values would be proposed for each sector based on alternate methodologies explained below. Each time the application of an alternate IMT or DD methodology resulted in a higher total revised AF, staff would award this higher revised AF from the alternate approach.

With regards to the IMT, staff would develop a secondary estimate of the international AF component for each sector based on a regression analysis. This regression analysis could be based on variables such as each sector's trade exposure, energy expenditures, and emissions intensity. Hereafter, this secondary estimate is termed the regression IMT. For sectors with regression IMT values larger than the IMT measured by the international study, the regression IMT would be used in the methodology instead of the IMT value measured by the international study, leading to a higher international AF component.

With regards to the domestic assistance factor component, staff would use a total of four DD estimates for each manufacturing sector (i.e., four possible domestic assistance factor components). The first two estimates are from the domestic research: decreases in domestic value added (profit), and domestic output (revenues) in response to the assumed $24.88 marginal compliance cost per $MTCO_2e$ (Table E-1 and Table E-2, respectively). Staff would then develop two additional regression estimates of DD based on the domestic value added drop and output drop. This regression estimate could be based on energy expenditures and/or emissions intensity. Counter to expectations, the domestic study estimated positive DD values for some sectors. The regression functional form would be chosen such that regression estimates of DD would be negative for all sectors, matching intuition. The domestic AF component would be calculated based on the most negative of these four DD estimates (i.e., the value that would result in the largest overall revised AF and highest level of allowance allocation). For non-studied sectors not covered by the international and domestic studies, as well as future entrants to the program, staff would use multiple methodologies to estimate DD values, and select the most favorable DD (i.e., DD resulting in the largest overall revised AF and highest level of allowance allocation) for use in these non-studied sectors.

### *c. Timeline for Revised Assistance Factor Application*

Staff proposes that the revised AFs be developed further, and if used to calculate allowance allocation, be applied starting in the fourth compliance period. Staff believes that these methods conservatively assess leakage risk for industrial sectors and yield revised AFs at a level to appropriately minimize emissions leakage risk for each sector. The method's inherent conservatism would lead to revised AFs higher than those needed to prevent potential emissions leakage, thus providing a limited amount of transition assistance. Regardless of the method applied for post-2020 allowance allocation and AFs, staff will continue to monitor emissions leakage potential and revisit leakage estimates on a periodic basis. Specific changes warranting a review, for example, would be significant increases in the allowance value, as well as increasing international adoption of climate regulation in other jurisdictions.

## B. Revised Emissions Leakage Prevention Methodology

### 1. Calculation of Overall Revised Assistance Factor

For all sectors, assistance factors for the fourth compliance period and beyond are calculated by summing an international AF component to minimize potential international leakage and a domestic AF component to minimize potential domestic leakage. Both components range between zero and 100 percent, and they are summed to yield the revised AF for a sector as follows:

revised AF = domestic AF component + international AF component (E-1)

Sections B.2 and B.3 of this appendix discuss details of the revised methodology that would develop international AF components and domestic AF components, respectively, for each manufacturing sector. Section B.4 discusses the details of the process that would develop the international AF component and domestic AF component for non-studied sectors.

### 2. Potential International Emissions Leakage for Manufacturing Sectors

#### *a. Potential International Emissions Leakage for Certain Manufacturing Sectors without Non-Purchased Fuel Emissions*

The international leakage study developed the international market transfer (IMT) metric to evaluate sector-specific leakage risk for the manufacturing sectors from domestic to foreign producers. IMT is the fraction of every dollar in decreased domestic output in response to a carbon signal that is offset by an increase in international production, and it is expected to be between zero and one. To calculate IMT for a sector, the international study used historical energy intensity (the fraction of industrial costs from energy purchases) and the carbon content of fuels and electricity to calculate the responsiveness, or elasticity, of domestic shipments, domestic exports, and foreign imports for the sector with respect to changes in domestic energy prices similar to the changes experienced upon implementation of a marginal compliance cost. For example, the elasticity of domestic exports with respect to domestic energy prices ("exp elasticity" below) is the percentage change in domestic exports with respect to a one percent increase in domestic energy prices ("|exp elasticity|" is the absolute value of this elasticity). In this appendix, these calculated IMTs are referred to as "raw" IMTs. The equation used to calculate the IMT, based on the international study[3] is as follows:

$$\text{Raw IMT} = (|\text{imp elasticity}| \times \text{imp} + |\text{exp elasticity}| \times \text{exp}) / (|\text{dom ship elasticity}| \times \text{dom ship}) \quad \text{(E-2)}$$

Where:

"imp" is the value of international imports to the U.S.;

"|imp elasticity|" is the absolute value (always positive) of the import elasticity;

"exp" is the value of international exports from the U.S.;

"|exp elasticity|" is the absolute value (always positive) of the export elasticity;

"dom ship" is the value of domestic shipments for both exports and domestic consumption; and

"|dom ship elasticity|" is the absolute value (always positive) of the domestic shipments elasticity.

Under the revised methodology, staff would also develop a second estimate of IMT, termed the "regression IMT." The regression IMT is developed to ensure industries receive a minimum international AF component relative to key industry characteristics (e.g., an industry's trade exposure). To develop the regression IMT for each sector, staff would run a regression between the raw IMT for each manufacturing industry and variables for the respective industry such as trade exposure, energy intensity, and emissions intensity. This process would provide coefficient(s) (e.g., $B_1$) of the relationship between the variable(s) and a sector's raw IMT, according to the following equation:

$$\text{Raw IMT}_i = F(\text{Variable } 1_i\ldots; B_{1\ldots}) \quad \text{(E-3)}$$

Where:

"Raw $IMT_i$" is sector i's IMT from the international study;

[3] Appendix F. *Fowlie, et al.*, p39

“F(Variable $1_i$…; $B_{1...}$)” is a function that would be determined based on variable selection;

“Variable $k_i$” is sector i's value for variable k (e.g., trade exposure); and

“$B_k$” is the industry-wide relationship between variable k, and raw IMT, based in part on the chosen functional form F(Variable $1_i$…; $B_{1...}$).

When calculating the overall revised assistance factor for a sector, staff would set the international assistance factor component equal to the higher value between the raw IMT and regression IMT. The regression IMT values are incorporated in the revised methodology because, as described in the international study, some of the sub-components used to calculate raw IMT values were noisy for some of the studied sectors. The regression IMT establishes a threshold for each sector below which final IMT values would not be set. As higher IMTs correspond with higher assistance factors, the regression IMT would guard against using raw IMT values in sectors where the raw IMT values are anomalously low.

Each industry’s regression IMT would be calculated using an equation such as equation E-4, where est$B_k$ is the estimated value of $B_k$ from the Equation E-3 regression:

Sector i regression IMT = F(Sector i variable 1…; est$B_1$…) (E-4)

Where:

“Sector i regression IMT” is sector i's calculated regression IMT;

“F(Sector i variable 1…; est$B_1$…)” is the same functional form as in equation E-3;

“Sector i variable k” is the sector-specific values of the respective variables, as used in equation E-3; and

“est$B_k$” is the estimate of the coefficient $B_k$ obtained from the equation E-3 regression.

Figure E-2 shows a raw IMT and regression IMT for a hypothetical sector. The raw IMT, based on the international study, is less than the regression IMT, based on the regression and sector-specific variables. When calculating the total revised AF by equation E-1 for this hypothetical sector, the international AF component would be assigned based on the higher regression IMT value.

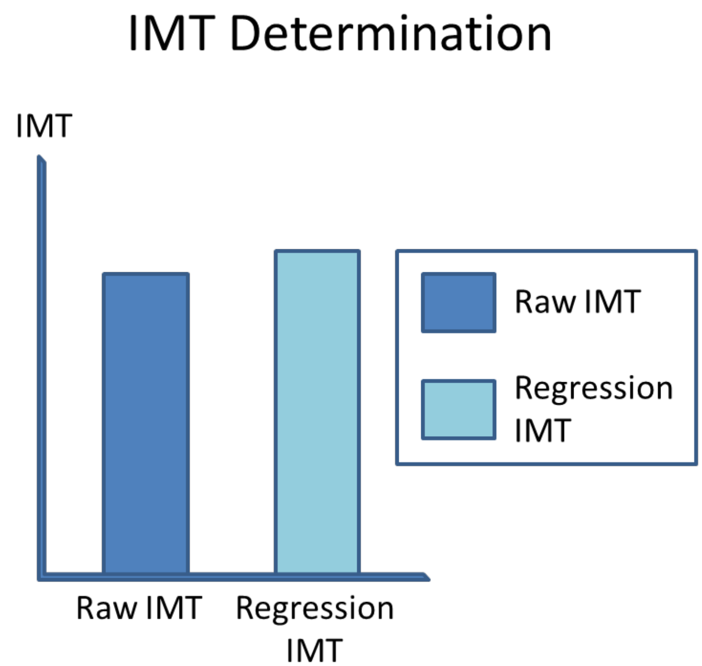


**Figure E-2. Raw IMT and Regression IMT for a Hypothetical Sector**

*b. Potential International Emissions Leakage for Manufacturing Sectors with Non-Purchased Fuel and/or Process Emissions*

For sectors that have non-purchased fuel emissions and/or process emissions in addition to energy-related emissions, staff would use an adjustment to the sector's regression IMT. Non-purchased fuel emissions include emissions from fuels not reported to the U.S. Census Bureau as part of the Annual Survey of Manufacturing (ASM) data used by the international study to establish the relationship between emissions, and changes in value added of each of domestic production, imports, and exports. For example, refinery fuel gas is a byproduct of onsite processes at refineries. Refineries do not purchase this fuel, so it is not included in the ASM data, but emissions from combusting refinery fuel gas incur a compliance obligation in the Program. Process emissions are non-combustion emissions, such as the calcination emissions arising from cement production. For sectors with non-purchased fuel and process emissions, variables used in calculating the regression IMT would be adjusted upwards as appropriate.

*c. Potential International Emissions Leakage for Food Processor Manufacturing Sectors*

Staff would use the IMTs from the international study to set the IMT values for most manufacturing sectors. For food processing sectors studied by the food processor study (i.e., some of the sectors with NAICS codes starting with 311), the raw IMT would also be informed by the market transfer rate from the food-processor-specific study as well as the IMT from the international study.

## 3. Potential Domestic Emissions Leakage for the Manufacturing Sector

### *a. Potential Domestic Leakage for Manufacturing Sectors without Non-Purchased Fuels and/or Process Emissions: Developing Domestic Drops*

The domestic leakage study used plant-level U.S. Census data to simulate the effects of a carbon-price-driven increase in operating costs on each manufacturing sector in California. The study measured the decrease in output, value added, and employment for each sector. The increase in California operating cost is driven by increased electricity and natural gas prices, which escalate with allowance prices. The domestic study simulated increased electricity and natural gas prices for a marginal compliance cost of $24.88 per $MTCO_2e$ in 2016 dollars with varying domestic AF components. Section 3c addresses sectors with non-purchased fuels and process emissions.

The revised methodology would use these simulations based on the decline in California value added or the decline in California output that is offset by leakage from California to other parts of the United States caused by the Program as calculated by the domestic study. Staff has also developed two additional domestic leakage estimates that would be applied, based on manufacturing-sector-wide regressions of the drop in value added or output on sector-specific values of variables such as energy intensity and emissions intensity, termed regressed domestic value added drop and regressed output drop respectively. Staff would base each sector's DD for application in developing the domestic AF components on the more negative (i.e., more favorable to the sector's allocation) of domestic value added drop, domestic output drop, regressed domestic value added drop, and regressed domestic output drop.

Domestic value added drop can be found in Table E-1. This table presents domestic value added drop values for a range of domestic AF component values from zero, indicating no allowance allocation up to 90 percent allowance allocation in 10 percent increments. Domestic value added drop for a given sector generally decreases to smaller negative values as the AF increases from left to right in the table, indicating that domestic value added decreases less in response to a marginal compliance cost as AF values increase. Domestic output drop can be found in Table E-2. Including domestic output drop in the revised methodology would increase revised AFs for some sectors for which it would be more negative than domestic value added drop, while never decreasing revised AFs for any sector.

For some California sectors, the domestic study calculated counterintuitive positive responses to increased energy prices. The revised methodology would still provide allocation for sectors with these counterintuitive responses. Broadly, if sectors had unexpectedly small and negative, or even positive changes in value added and/or output in response to the compliance cost, staff would adjust the response downward to match an average level of decrease in value added and/or output based on sectors with similar values of relevant variables such as energy intensity and emissions intensity. While some individual sectors had counterintuitive positive responses in Table E-1 and

Table E-2, the trend of the overall manufacturing sector conforms with expectations: value added and output decrease in response to increased energy prices, and the impacts are more negative for sectors with higher energy intensities. For sectors with the highest energy intensities, value added and output drops from the domestic research were among the most negative. Many of these sectors also have high emissions intensities.

Similar to the regression IMT approach used to develop alternate estimates of the international assistance factor component, staff would develop a regression to correlate domestic value added drop to industry-specific variables such as energy intensity and emissions intensity (Equation E-6). Staff would also develop a regression correlating the relationship between output drop and the same industry-specific variables.

The proposed domestic value added drop regression would be as follows:

$$DVA_{i,study,0} = F(\text{Variable } 1_i \ldots; B_1 \ldots) \qquad \text{(E-6)}$$

Where:

"$DVA_{i,study,0}$" is the domestic value added drop for sector "i" with zero assistance factor from the domestic study, which can be found in table A1 of the domestic study;

"F(Variable 1i …; $B_1$ …)" is the functional form relating the industry-specific variables to DVA;

"Variable $k_i$" is the industry i's value of variable k; and

"$B_k$" is the manufacturing-sector-wide relationship between variable k and DVA with a zero AF, in part based on the chosen functional form F(Variable $1_i$ …; $B_1$ …).

The regressed domestic value added drop with a zero assistance factor for a sector is then calculated by the following equation:

$$DVA_{i,regressed,0} = F(\text{Variable } 1_i \ldots; estB_1 \ldots) \qquad \text{(E-7)}$$

Where:

"$DVA_{i,regressed,0}$" is the regression domestic value added drop for sector "i" with zero assistance factor;

"F(Variable $1_i$ …; $estB_1$ …)" is the same functional form as in Equation E-6; and

"$estB_k$" is the estimate of the coefficient $B_k$ obtained from equation E-6.

With the regression domestic value added drop at zero assistance factor established for each sector, staff would then calculate regressed DVA values at increasing levels of AF based on the following formula:

$$DVA_{i,regressed,X} = F(DVA_{i,regressed,0},X) \qquad \text{(E-8)}$$

Where:

“$DVA_{i,regressed,X}$” is the regression domestic value added drop for sector “i” with an assistance factor equal to X; and

“F($DVA_i$,regressed,0,X)” is the functional form relating $DVA_{i,regressed,0}$, the assistance factor X, and the calculated regressed DVA.

Regressed output drop is calculated using the same general method as regressed value added drop:

$$Output\ Drop_{i,study,0} = F(Variable\ 1_i\ \ldots;\ B_1\ \ldots) \qquad \text{(E-9)}$$

Where:

“$Output\ Drop_{i,study,0}$” is the domestic output drop for sector “i” with a zero assistance factor;

“F(Variable $1_i$ …; $B_1$ …)” is the functional form relating the industry-specific variables to output drop;

“Variable $k_i$” is the industry i's value of variable k; and

“$B_k$” is the manufacturing-sector-wide relationship between variable k and output drop with a zero AF, in part based on the chosen functional form F(Variable $1_i$ …; $B_1$ …).

Each sector’s regressed domestic output drop with a zero assistance factor is then calculated by the following equation:

$$Output\ Drop_{i,regressed,0} = F(Variable\ 1_i\ \ldots;\ estB_1\ \ldots) \qquad \text{(E-10)}$$

Where:

“$Output\ Drop_{i,regressed,0}$” is the regression domestic output drop for sector “i” with zero assistance factor;

“F(Variable $1_i$ …; est$B_1$ …)” is the same functional form as in Equation E-9; and

“est$B_k$” is the estimate of the coefficient $B_k$ resulting from equation E-9.

With the regression domestic out drop at zero assistance factor established for each sector, staff would then calculate regressed domestic output drop values at increasing levels of AF based on the following formula:

$$\text{Output Drop}_{i,regressed,X} = F(\text{Output Drop}_{i,regressed,0}, X) \quad \text{(E-11)}$$

Where:

"$\text{Output Drop}_{i,regressed,X}$" is the regression domestic output drop for sector "i" with an assistance factor equal to X; and

"$F(\text{Output Drop}_{i,regressed,0}, X)$" is the functional form relating "$\text{Output Drop}_{i,regressed,0}$", the assistance factor X, and the calculated regressed domestic output drop.

*b. Applying Domestic Drops to Obtain Domestic Assistance Factor Components*

The four methodologies to estimate DD conservatively assume a one-for-one tradeoff between a decline in California output and an increase in non-California domestic output. Because of this one-for-one assumption, staff cannot simply translate the DD values from section 3a into the domestic AF component for each sector in the same way that the IMT values could be translated into the international AF component. Instead, as discussed earlier, staff would apply a cutoff DD based on an assumed $24.88 per $MTCO_2e$ marginal compliance cost.

To set a domestic AF component value for each sector based on the cutoff DD, staff would estimate the domestic AF component implied by each of the four DD estimates (value added drop, output drop, regressed value added drop, and regressed output drop), and select the highest resulting domestic AF component as the component for use in determining the (total) revised AF using equation E-1. Using each methodology, the domestic AF component would be increased from zero until the DD value for each method would be above the cutoff DD.

Figure E-3 shows a hypothetical sector A for which the output drop from the domestic study is more negative than the other three DD metrics. In this case, the necessary domestic AF component to prevent value added drop (the left-most column) from exceeding the cutoff DD is a "b" percent domestic AF component. To prevent output drop (the second column) from exceeding the cutoff DD, a "c" domestic AF component is required. The necessary assistance factor to prevent regressed value added (the third column) from exceeding the cutoff DD is an "a" percent domestic AF component. Finally, to prevent regressed output (the right-most column) from exceeding the cutoff DD, a "b" percent domestic AF component is needed. For each sector, the highest domestic AF component is applied, so this sector is assigned a domestic AF component equal to "c" percent that is derived from the output drop calculation.

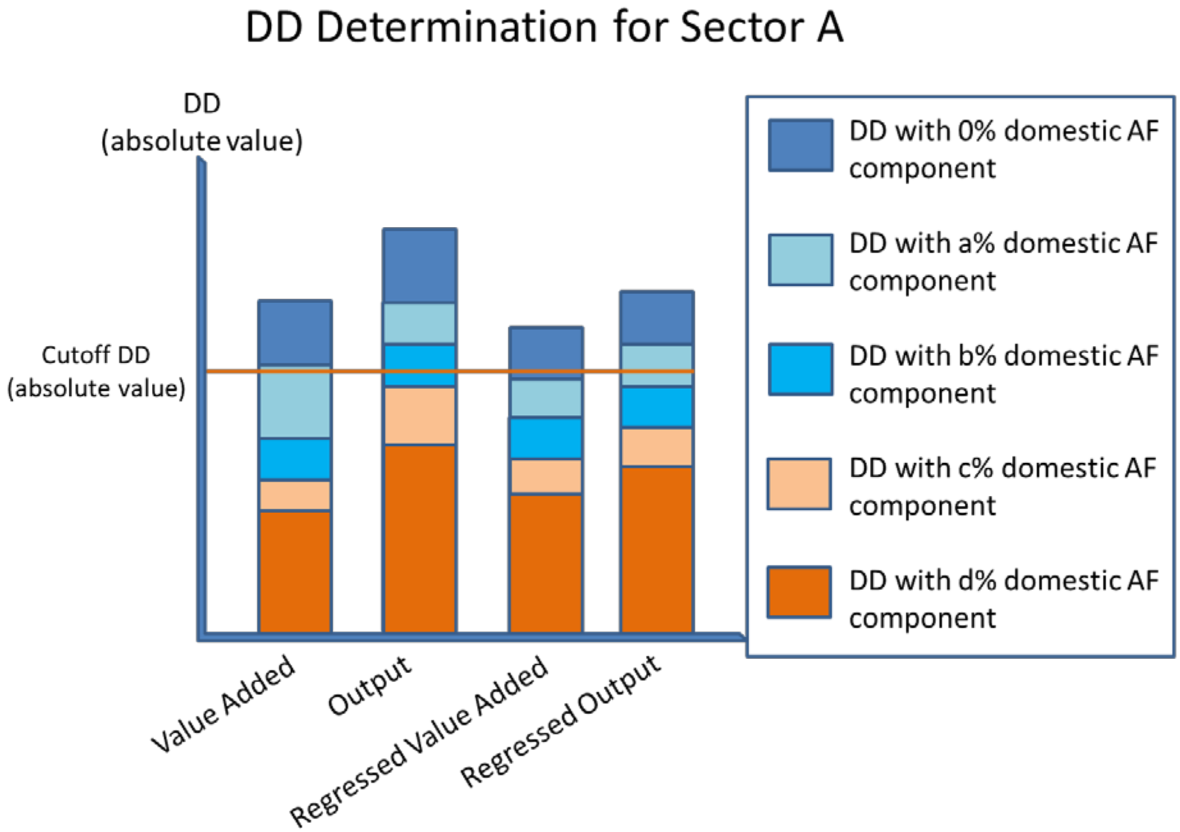


**Figure E-3. Determination of the Domestic Assistance Factor Component by Output Drop from the Domestic Study for Hypothetical Sector A.**

Figure E-4 shows another hypothetical sector B for which regressed value added requires a greater domestic AF component in order to prevent the (regressed value added) DD from exceeding the cutoff DD.  In this case, the sector would be assigned a "c" percent domestic AF based on the regressed value added drop calculation.

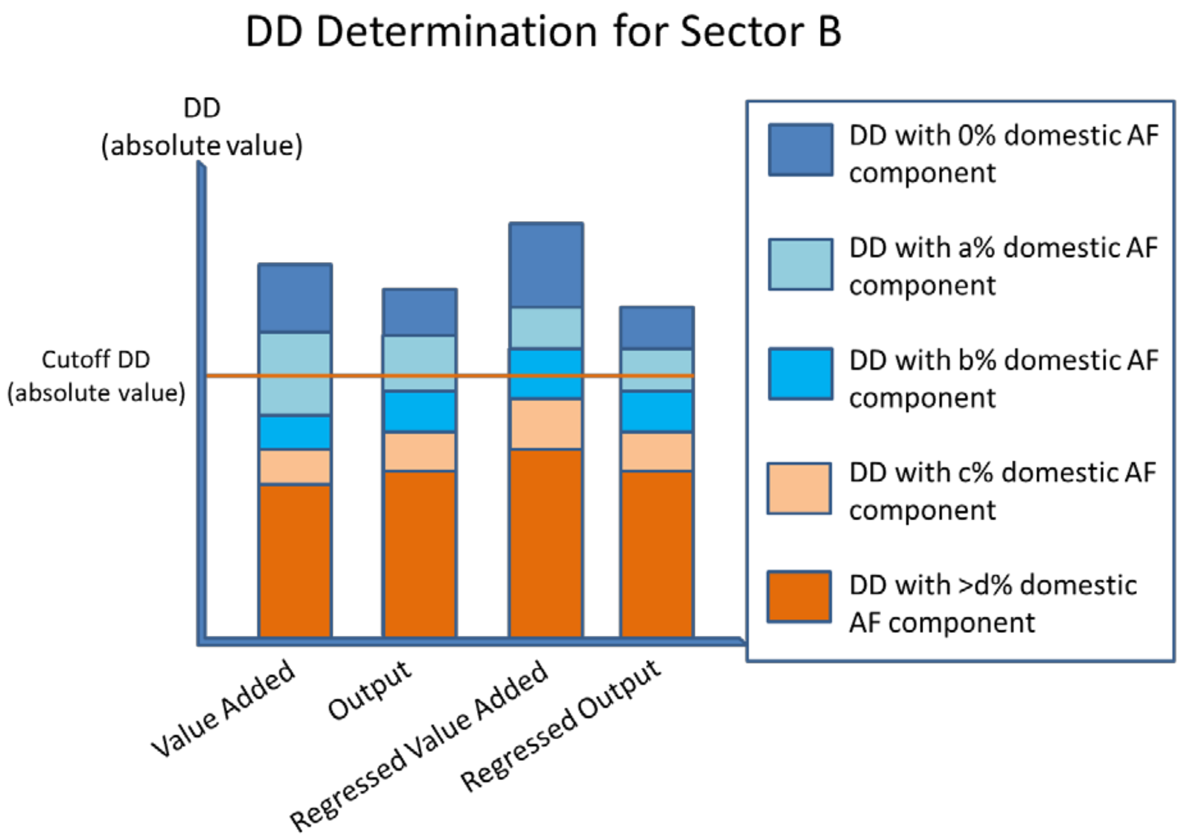


**Figure E-4: Determination of the Domestic Assistance Factor Component by Regressed Value Added Drop for Hypothetical Sector B.**

*c. Potential Domestic Emissions Leakage for Manufacturing Sectors with Non-Purchased Fuel and/or Process Emissions*

For sectors with non-purchased fuel, significant purchased fuels from fuel types that don't closely track natural gas or electricity prices, or process emissions—variables used to calculate the regressed value added and regressed output (i.e., in two of the four DD estimation methodologies)—would be adjusted upward as appropriate under the revised methodology. This upward adjustment would result in a higher domestic AF component for these sectors relative to excluding consideration of non-purchased fuel and/or process emissions.

## 4. Potential Emissions Leakage for Sectors Not Evaluated by the Studies

*a. Overview*

The three commissioned studies analyzed potential industrial emissions leakage risk for manufacturing sectors covered by the Cap-and-Trade Program (i.e., sectors assigned a NAICS code starting with 3). Non-manufacturing sectors with NAICS codes starting with 1, 2, and 4 were not analyzed by these studies. Because raw IMT, (domestic study) value added DD, and (domestic study) output DD values for these non-studied sectors are unavailable, emissions leakage potentials for these sectors would be estimated by matching each non-studied sector based on its attributes selected as variables for use in calculating studied-sector regressed DD values (i.e., variables selected for use in Equations E-6 and E-9).

*b. International AF Component for Non-Studied Sectors*

For the international AF component (IMT) of a non-studied sector, data would be collected of each non-studied sector's variables that were used in the studied sector regressed IMT calculation (Equations E-3 and E-4). These variables would then be used to calculate a regressed IMT value using equation E-4, and these (non-studied) sector-specific regressed IMT values would be used as the international AF component for the non-studied sectors.

*c. Domestic AF Component for Non-Studied Sectors*

The domestic study used electricity and natural gas consumption to determine the fraction of expenditures coming from energy consumption ("energy intensity"). Should energy intensity be used in determining DD for non-studied sectors, these estimates should be based on sources of financial expenditure information consistent with information available for the studied sectors. This ensures domestic study energy intensity estimates are comparable across industries.

Domestic value added drop with a zero AF would be correlated for the manufacturing sector using the following equation:

$$DVA_{i,manufacturing,0} = F(\text{Public Variable } 1_i, \ldots; B_1 \ldots) \qquad \text{(E-12)}$$

Where:

"$DVA_{i,manufacturing,0}$" is the domestic value added drop for manufacturing sector "i" with zero assistance factor from the domestic study, which can be found in table A1 of the domestic study;

"$F(\text{Public Variable } 1_i, \ldots; B_1 \ldots)$" is the functional form relating the public variables to "$DVA_{i,manufacturing,0}$" common across all studied (and non-studied) sectors; and

"Public Variable $k_i$" is variable k for the manufacturing sector "i" determined from public data sources.

Each non-studied sector's regressed domestic value added drop with a zero assistance factor would then be calculated by the following equation:

$$DVA_{j,regressed,0} = F(\text{Public Variable } 1_j, \ldots; estB_1, \ldots) \qquad \text{(E-13)}$$

Where:

"$DVA_{j,regressed,0}$" is the regression domestic value added drop for non-studied sector "j" with a zero assistance factor;

"F(Public Variable $1_j$,…; $estB_1$,…)" is the same functional form as in Equation E-12; and

"$estB_k$" is the estimate of the coefficient $B_k$ resulting from equation E-12.

The regressed domestic value added drop with increasing assistance factors for each non-studied sector "j" is then calculated by the following equation:

$$DVA_{j,regressed,X} = F(DVA_{j,regressed,0},X) \qquad \text{(E-14)}$$

Where:

"$DVA_{j,regressed,X}$" is the regression domestic value added drop for non-studied sector "j" with an assistance factor equal to X; and

"F($DVA_{j,regressed,0}$,X)" is the functional form relating "$DVA_{j,regressed,0}$", the assistance factor X, and the calculated regressed domestic value added drop for the non-studied sector "j."

The relationship between domestic output drop and U.S. Census energy intensity for non-studied sectors is determined in the same manner as for domestic value added drop:

$$\text{Output Drop}_{i,manufacturing,0} = F(\text{Public Variable } 1_i,\ldots;\ B_1\ldots) \qquad \text{(E-15)}$$

Where:

"Output $Drop_{i,manufacturing,0}$" is the domestic output drop for manufacturing sector "i" with zero assistance factor from the domestic study;

"F(Public Variable $1_i$,…; $B_1$…)" is the functional form relating the public variables to "$DVA_{i,manufacturing,0}$" common across all studied (and non-studied) sectors; and

"Public Variable $k_i$" is variable k for the manufacturing sector "i" determined from public data sources.

Each non-studied sector's regressed domestic output drop with a zero assistance factor is then calculated by the following equation:

$$\text{Output Drop}_{j,regressed,0} = F(\text{Public Variable } 1_j,\ldots;\ estB_1\ldots) \qquad \text{(E-16)}$$

Where:

"$Output\ Drop_{j,regressed,0}$" is the regression domestic output drop for non-studied sector "j" with zero assistance factor;

"F(Public Variable $1_j$,…; $estB_1$…)" is the same functional form as in Equation E-15; and

"$estB_k$" is the estimate of the coefficient $B_k$ resulting from equation E-15.

The regressed domestic output drop with increasing assistance factors for each non-studied sector "j" is calculated by the following equation:

$$Output\ Drop_{j,regressed,X} = F(Output\ Drop_{j,regressed,0}, X) \qquad (E\text{-}17)$$

Where:

"$Output\ Drop_{j,regressed,X}$" is the regression domestic output drop for non-studied sector "j" with an assistance factor equal to X; and

"$F(Output\ Drop_{j,regressed,0},X)$" is the functional form relating "$Output\ Drop_{j,regressed,X}$", the assistance factor X, and the calculated regressed domestic output drop for the non-studied sector "j".

For each non-studied sector, the final domestic AF component would be the larger of the two determined domestic AF components based on the cutoff DD value.

*d. Potential Emissions Leakage for Sectors with Non-Purchased Fuels and/or Process Emissions Not Evaluated by the Studies*

Some non-studied sectors have process emissions and emissions associated with non-purchased fuels.  Variables used in developing IMT and DD for these sectors would be adjusted upward as appropriate to account for these emissions

The determination of IMTs and DDs for these sectors would otherwise follow the methodology of non-studied sectors without process emissions and/or emissions associated with non-purchased fuels.

*e. Future Non-Studied Sectors*

After potential implementation of the revised methodology, new entrants eligible for emissions leakage protection would be assigned a revised AF.  This revised assistance factor could use the methodology developed for the non-studied sectors.

## C. Tables

**Table E-1. Domestic Value Added DDs for Each Studied Sector at Assistance Factors from Zero to 90 Percent (Percentages).**

| NAICS Code | 0AF | 10AF | 20AF | 30AF | 40AF | 50AF | 60AF | 70AF | 80AF | 90AF |
|---|---|---|---|---|---|---|---|---|---|---|
| 311313 | -15.5 | -14.0 | -12.5 | -11.0 | -9.4 | -7.9 | -6.4 | -4.8 | -3.2 | -1.6 |
| 311421 | -2.9 | -2.6 | -2.4 | -2.1 | -1.8 | -1.5 | -1.2 | -0.9 | -0.6 | -0.3 |
| 311423 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | 0.0 | 0.0 | 0.0 |
| 311512 | -3.4 | -3.0 | -2.7 | -2.4 | -2.1 | -1.8 | -1.4 | -1.1 | -0.7 | -0.4 |
| 311513 | -15.5 | -14.0 | -12.5 | -11.0 | -9.4 | -7.9 | -6.4 | -4.8 | -3.2 | -1.6 |
| 311514 | 3.0 | 2.8 | 2.5 | 2.2 | 1.9 | 1.6 | 1.3 | 1.0 | 0.7 | 0.3 |
| 311611 | -6.4 | -5.8 | -5.2 | -4.6 | -3.9 | -3.3 | -2.7 | -2.0 | -1.3 | -0.7 |
| 311613 | -2.1 | -1.9 | -1.7 | -1.5 | -1.3 | -1.1 | -0.9 | -0.7 | -0.5 | -0.2 |
| 311615 | -14.5 | -13.1 | -11.7 | -10.3 | -8.9 | -7.5 | -6.0 | -4.5 | -3.0 | -1.5 |
| 311911 | -22.6 | -20.5 | -18.3 | -16.1 | -13.9 | -11.7 | -9.4 | -7.1 | -4.8 | -2.4 |
| 311919 | -14.5 | -13.1 | -11.7 | -10.3 | -8.9 | -7.4 | -6.0 | -4.5 | -3.0 | -1.5 |
| 312120 | -6.5 | -5.9 | -5.3 | -4.6 | -4.0 | -3.3 | -2.7 | -2.0 | -1.4 | -0.7 |
| 312130 | -15.5 | -14.0 | -12.5 | -11.0 | -9.4 | -7.9 | -6.4 | -4.8 | -3.2 | -1.6 |
| 322121 | 3.9 | 3.6 | 3.2 | 2.8 | 2.5 | 2.1 | 1.7 | 1.3 | 0.9 | 0.4 |
| 322130 | -15.9 | -14.4 | -12.9 | -11.3 | -9.8 | -8.2 | -6.6 | -5.0 | -3.3 | -1.7 |
| 324110 | 7.4 | 6.8 | 6.1 | 5.4 | 4.7 | 3.9 | 3.2 | 2.4 | 1.6 | 0.8 |
| 324121 | -7.8 | -7.1 | -6.3 | -5.6 | -4.8 | -4.0 | -3.2 | -2.4 | -1.6 | -0.8 |
| 324199 | -2.6 | -2.3 | -2.1 | -1.9 | -1.6 | -1.4 | -1.1 | -0.8 | -0.6 | -0.3 |
| 325120 | -14.8 | -13.4 | -11.9 | -10.5 | -9.1 | -7.6 | -6.1 | -4.6 | -3.1 | -1.6 |
| 325188 | -15.4 | -13.9 | -12.5 | -11.0 | -9.5 | -7.9 | -6.4 | -4.8 | -3.2 | -1.6 |
| 325193 | -14.5 | -13.1 | -11.7 | -10.3 | -8.9 | -7.4 | -6.0 | -4.5 | -3.0 | -1.5 |
| 325199 | -20.9 | -18.9 | -16.9 | -14.8 | -12.8 | -10.7 | -8.6 | -6.5 | -4.4 | -2.2 |
| 325311 | -11.8 | -10.7 | -9.6 | -8.4 | -7.2 | -6.1 | -4.9 | -3.7 | -2.5 | -1.2 |
| 325412 | -11.2 | -10.1 | -9.0 | -7.9 | -6.8 | -5.7 | -4.5 | -3.4 | -2.3 | -1.1 |

| NAICS Code | 0AF | 10AF | 20AF | 30AF | 40AF | 50AF | 60AF | 70AF | 80AF | 90AF |
|---|---|---|---|---|---|---|---|---|---|---|
| 325414 | -8.4 | -7.6 | -6.8 | -6.0 | -5.1 | -4.3 | -3.5 | -2.6 | -1.8 | -0.9 |
| 327211 | 5.7 | 5.1 | 4.6 | 4.1 | 3.5 | 3.0 | 2.4 | 1.8 | 1.2 | 0.6 |
| 327213 | -20.9 | -18.9 | -16.9 | -14.8 | -12.8 | -10.7 | -8.6 | -6.5 | -4.4 | -2.2 |
| 327310 | -35.7 | -32.3 | -28.9 | -25.4 | -21.9 | -18.4 | -14.8 | -11.1 | -7.5 | -3.8 |
| 327410 | -24.7 | -22.3 | -20.0 | -17.6 | -15.1 | -12.7 | -10.2 | -7.7 | -5.2 | -2.6 |
| 327420 | -20.9 | -18.9 | -16.9 | -14.8 | -12.8 | -10.7 | -8.6 | -6.5 | -4.4 | -2.2 |
| 327993 | -13.9 | -12.6 | -11.2 | -9.9 | -8.5 | -7.1 | -5.7 | -4.3 | -2.9 | -1.5 |
| 331111 | -24.8 | -22.4 | -20.1 | -17.6 | -15.2 | -12.7 | -10.2 | -7.7 | -5.2 | -2.6 |
| 331221 | -24.8 | -22.4 | -20.0 | -17.6 | -15.2 | -12.7 | -10.2 | -7.7 | -5.2 | -2.6 |
| 331314 | 16.1 | 14.6 | 13.1 | 11.6 | 10.0 | 8.4 | 6.8 | 5.1 | 3.5 | 1.7 |
| 331492 | -12.5 | -11.3 | -10.1 | -8.9 | -7.7 | -6.4 | -5.2 | -3.9 | -2.6 | -1.3 |
| 331511 | -13.7 | -12.4 | -11.1 | -9.8 | -8.4 | -7.1 | -5.7 | -4.3 | -2.9 | -1.4 |
| 332112 | -13.3 | -12.0 | -10.7 | -9.4 | -8.1 | -6.8 | -5.5 | -4.1 | -2.8 | -1.4 |
| 332510 | -10.8 | -9.8 | -8.8 | -7.7 | -6.6 | -5.6 | -4.5 | -3.4 | -2.3 | -1.1 |
| 333611 | -0.5 | -0.5 | -0.4 | -0.4 | -0.3 | -0.3 | -0.2 | -0.2 | -0.1 | 0.0 |
| 336411 | -3.6 | -3.2 | -2.8 | -2.5 | -2.1 | -1.7 | -1.4 | -1.0 | -0.7 | -0.3 |
| 336414 | -6.6 | -6.0 | -5.4 | -4.7 | -4.1 | -3.4 | -2.8 | -2.1 | -1.4 | -0.7 |

**Table E-2. Domestic Output DDs for Each Studied Sector at Assistance Factors from Zero to 90 Percent (Percentages).**

| NAICS Code | 0AF | 10AF | 20AF | 30AF | 40AF | 50AF | 60AF | 70AF | 80AF | 90AF |
|---|---|---|---|---|---|---|---|---|---|---|
| 311313 | -4.5 | -4.1 | -3.7 | -3.2 | -2.8 | -2.3 | -1.9 | -1.4 | -1.0 | -0.5 |
| 311421 | -6.7 | -6.1 | -5.5 | -4.9 | -4.2 | -3.5 | -2.9 | -2.2 | -1.5 | -0.7 |
| 311423 | -4.4 | -4.0 | -3.6 | -3.2 | -2.7 | -2.3 | -1.9 | -1.4 | -0.9 | -0.5 |
| 311512 | -17.8 | -16.1 | -14.4 | -12.7 | -10.9 | -9.2 | -7.4 | -5.6 | -3.7 | -1.9 |
| 311513 | 2.2 | 2.0 | 1.8 | 1.6 | 1.4 | 1.2 | 1.0 | 0.7 | 0.5 | 0.2 |
| 311514 | -8.1 | -7.3 | -6.5 | -5.7 | -5.0 | -4.2 | -3.4 | -2.5 | -1.7 | -0.9 |
| 311611 | -5.3 | -4.8 | -4.3 | -3.8 | -3.3 | -2.7 | -2.2 | -1.7 | -1.1 | -0.6 |
| 311613 | -16.3 | -14.8 | -13.2 | -11.7 | -10.1 | -8.4 | -6.8 | -5.1 | -3.4 | -1.7 |
| 311615 | -23.3 | -21.1 | -18.9 | -16.7 | -14.4 | -12.1 | -9.7 | -7.3 | -4.9 | -2.5 |
| 311991 | -4.9 | -4.4 | -3.9 | -3.4 | -3.0 | -2.5 | -2.0 | -1.5 | -1.0 | -0.5 |
| 311999 | -11.3 | -10.2 | -9.1 | -8.1 | -6.9 | -5.8 | -4.7 | -3.5 | -2.4 | -1.2 |
| 312120 | -17.8 | -16.1 | -14.4 | -12.7 | -10.9 | -9.2 | -7.4 | -5.6 | -3.7 | -1.9 |
| 312130 | 4.3 | 3.9 | 3.5 | 3.1 | 2.7 | 2.2 | 1.8 | 1.4 | 0.9 | 0.5 |
| 322121 | -14.6 | -13.2 | -11.8 | -10.4 | -8.9 | -7.5 | -6.0 | -4.5 | -3.0 | -1.5 |
| 322130 | -31.2 | -28.2 | -25.2 | -22.2 | -19.1 | -16.1 | -12.9 | -9.7 | -6.5 | -3.3 |
| 324110 | -13.2 | -11.9 | -10.7 | -9.4 | -8.1 | -6.8 | -5.5 | -4.1 | -2.8 | -1.4 |
| 324121 | -3.8 | -3.4 | -3.1 | -2.7 | -2.4 | -2.0 | -1.6 | -1.2 | -0.8 | -0.4 |
| 324199 | -13.3 | -12.1 | -10.8 | -9.5 | -8.2 | -6.8 | -5.5 | -4.1 | -2.8 | -1.4 |
| 325120 | -16.7 | -15.1 | -13.5 | -11.9 | -10.3 | -8.6 | -6.9 | -5.2 | -3.5 | -1.8 |
| 325188 | -14.5 | -13.2 | -11.8 | -10.4 | -8.9 | -7.5 | -6.0 | -4.5 | -3.0 | -1.5 |
| 325193 | -22.6 | -20.5 | -18.3 | -16.1 | -13.9 | -11.6 | -9.4 | -7.1 | -4.7 | -2.4 |
| 325199 | -16.6 | -15.1 | -13.5 | -11.9 | -10.2 | -8.6 | -6.9 | -5.2 | -3.5 | -1.8 |
| 325311 | -20.8 | -18.8 | -16.8 | -14.8 | -12.7 | -10.7 | -8.6 | -6.5 | -4.3 | -2.2 |
| 325412 | -10.3 | -9.4 | -8.4 | -7.4 | -6.4 | -5.3 | -4.3 | -3.2 | -2.2 | -1.1 |

| NAICS Code | 0AF | 10AF | 20AF | 30AF | 40AF | 50AF | 60AF | 70AF | 80AF | 90AF |
|---|---|---|---|---|---|---|---|---|---|---|
| 325414 | 5.3 | 4.8 | 4.3 | 3.8 | 3.3 | 2.8 | 2.3 | 1.7 | 1.2 | 0.6 |
| 327211 | -22.6 | -20.5 | -18.3 | -16.1 | -13.9 | -11.6 | -9.4 | -7.1 | -4.7 | -2.4 |
| 327213 | -37.5 | -33.9 | -30.3 | -26.7 | -23.0 | -19.3 | -15.5 | -11.7 | -7.9 | -4.0 |
| 327310 | -20.5 | -18.5 | -16.5 | -14.5 | -12.5 | -10.5 | -8.4 | -6.3 | -4.2 | -2.1 |
| 327410 | -22.6 | -20.5 | -18.3 | -16.1 | -13.9 | -11.6 | -9.4 | -7.1 | -4.7 | -2.4 |
| 327420 | -16.0 | -14.4 | -12.9 | -11.4 | -9.8 | -8.2 | -6.6 | -5.0 | -3.4 | -1.7 |
| 327993 | -22.8 | -20.6 | -18.4 | -16.2 | -14.0 | -11.7 | -9.4 | -7.1 | -4.7 | -2.4 |
| 331111 | -26.7 | -24.1 | -21.6 | -19.0 | -16.4 | -13.7 | -11.0 | -8.3 | -5.6 | -2.8 |
| 331221 | 18.4 | 16.7 | 15.0 | 13.2 | 11.4 | 9.6 | 7.8 | 5.9 | 4.0 | 2.0 |
| 331314 | -11.7 | -10.6 | -9.5 | -8.4 | -7.2 | -6.0 | -4.9 | -3.7 | -2.5 | -1.2 |
| 331492 | -7.3 | -6.6 | -5.8 | -5.1 | -4.4 | -3.7 | -2.9 | -2.2 | -1.5 | -0.7 |
| 331511 | -21.6 | -19.5 | -17.4 | -15.4 | -13.2 | -11.1 | -8.9 | -6.7 | -4.5 | -2.3 |
| 332112 | -13.0 | -11.8 | -10.5 | -9.3 | -8.0 | -6.7 | -5.4 | -4.1 | -2.7 | -1.4 |
| 332510 | -2.3 | -2.0 | -1.8 | -1.6 | -1.4 | -1.2 | -0.9 | -0.7 | -0.5 | -0.2 |
| 333611 | -17.8 | -16.1 | -14.4 | -12.7 | -10.9 | -9.2 | -7.4 | -5.6 | -3.7 | -1.9 |
| 336411 | -7.6 | -6.9 | -6.2 | -5.4 | -4.7 | -3.9 | -3.2 | -2.4 | -1.6 | -0.8 |
| 336414 | -2.8 | -2.5 | -2.2 | -2.0 | -1.7 | -1.4 | -1.2 | -0.9 | -0.6 | -0.3 |

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