The Cost-effectiveness of Alternative Emission Control Policies in the San Joaquin Valley of California

Hong Jin Kim* · Yongsung Cho**

I. Introduction

Traditional emission command-and-control (CAC) approaches have been criticized as more costly than marketable emission permit systems to

---

* National Center for Environmental Economics (Mailcode=1809) U.S. Environmental Protection Agency.
** Department of Food and Resource Economics, Korea University.
meet a required emission reduction or to achieve a desired air quality. In marketable permit systems, polluters with higher costs for emission control buy permits from polluters with lower costs, and as a result, total aggregate abatement costs can be reduced. The most cost-effective permit system to achieve a desired air quality would be ambient permit system (APS) in which stationary sources can freely trade their emission permits based on their differentiated contribution to the same receptors.\textsuperscript{1)} This approach, however, is not always taken into consideration because of its difficulty of obtaining spatial dispersion characteristics of emissions from stationary sources to receptors.

Uniform marketable permit system (UMPS) is the least-cost strategy to meet a required reduction in total emissions. This system allows one-to-one permits trading under the assumption that all emission sources have the same impact on air quality in a region. A shortcoming of this system is that hot spots\textsuperscript{2)} can be created after trading emission permits from less polluted area to more polluted area in a region.

Localized marketable permit system (LMPS) allows free trading of their emission permits on one-to-one basis as long as the sources locate within same parts of a region, in which emissions are considered to have the same effects on the receptors. LMPS may result in cost savings from the traditional standards-based approaches and it also can considerably reduce the possibility that hot spots are created. However, it is not as cost-effective as APS due to limited possibility of permits trading.

Many studies\textsuperscript{3)} have found that marketable permit systems are more

\textsuperscript{1)} A receptor is a geographical area in which air quality is affected by the emission sources. For example, a city can be considered as a receptor.

\textsuperscript{2)} Receptor sites that violate air quality standards.
cost-effective than standard-based approaches in achieving the required emission reduction or the given air quality objectives. However, only a few studies are available for empirical comparison among different marketable permits designs at a regional level in terms of their cost-effectiveness and possibility of creating hot spots.4)

Atkinson and Tietenberg (1982) examined the cost-effectiveness of LMPS with the control cost data for particulate emission controls from 27 stationary sources in the St. Louis Air Quality Control Region (AQCR). They found that LMPS were 30 to 70 percent less costly than the state CAC policies, but still significantly higher than APS and UMPS. ICF Resources (1989) found that inter-state SO₂ emission trading among electric utilities could reduce compliance cost for the new SO₂ regulations from 65% to 95%, while trading only within a plan could still save up to 60% of the compliance cost.

The California state policy directed at reducing reactive organic gases (ROG) emissions from stationary sources has been largely on emission standards with limited use of emission permits. The current permit systems, however, have many restrictions on emission permit trading. For example, new sources are allowed to buy emission reduction credits only if they control their emissions to the lowest achievable emission rate (LAER). Existing sources with significantly higher emission rates than the standards are not allowed to buy emission reduction credits without reducing their emissions to LAER standard.5) Each sources with different

impacts on a regional air quality are often prevented from trading their spatially differentiated permits due to its complexity involved.

A feasible permit system that can provide cost-savings from the current system in the San Joaquin Valley of California would be LMPS. All sources can freely trade their permits on one-to-one basis if they locate in the same local areas. It would not significantly distort the effectiveness of APS because stationary sources are clustered into a few cities within which their emissions can be considered to have the same impact on air quality in the San Joaquin Valley. LMPS also can prevent hot spots from being created. Because of the spatial distribution of the cities in which stationary sources are clustered in the San Joaquin Valley that lies over about 400 miles long, one-to-one permits trading among sources across remote cities can easily create hot spots.

The objective of this paper is to examine relative cost-effectiveness and assurance of achieving desired air quality associated with the three different emission control policies in the San Joaquin Valley of California: traditional command-and-control (CAC) policy represented by uniform percentage reductions of emissions across all stationary sources, localized marketable permit system (LMPS), and uniform marketable permit system (UMPS).

II. The Model

The net benefit of ROG emission control would be maximized at the

optimal control level. The optimization problem can be defined as finding the set of $X_j$ which maximize:

$$\text{Max} \sum_{i=1}^{n} \sum_{j=1}^{m} B_{ij}(X_j^{Optimal}) - \sum_{j=1}^{m} C_j(X_j^{Optimal})$$

(1)

where, $B_{ij}$ denotes the benefits of $i^{th}$ receptor due to emission controls from $j^{th}$ source ($i=1,\ldots,n$, receptors and $j=1,\ldots,m$, emission sources). $C_j$ denotes the total control costs of $j^{th}$ source and $X_j^{Optimal}$ is the optimal control level from $j^{th}$ source.

Assuming that second-order conditions are well behaved, the first-order conditions (FOCs) for this optimization problem are:

$$\sum_{i=1}^{n} MB_{ij}(X_j^{Optimal}) = MC_j(X_j^{Optimal})$$

(2)

The social optimum will be achieved if marginal control costs of the $j^{th}$ source, $MC_j$, equal the sum of $n$ receptors’ marginal benefit due to emission controls on the $j^{th}$ source. The resulting optimal level of control for the $j^{th}$ source is $X_j^{Optimal}$. In practice, this social optimum is very difficult to identify, because estimating the benefit functions for all the receptors is difficult.

1. Ambient Permit System (APS)

Current policy approaches to controlling air pollution focus on alternative policies for achieving a given air quality goal. One such policy
is to minimize the costs of achieving a certain ambient air quality standard. The problem can be formulated as:

\[
\begin{align*}
\text{Min} & \quad \sum_{j=1}^{m} C_j(X_j^{\text{Ambient}}) \\
\text{s.t.} & \quad \sum_{j=1}^{m} a_{ij} X_j^{\text{Ambient}} \geq E_i, \quad i = 1, \ldots, n
\end{align*}
\]  

(3)

where, \( a_{ij} \) indicates the linear transfer coefficient that relates emission reductions from the \( j^{th} \) source to air quality at the \( i^{th} \) receptor. \( E_i \) is the emission reduction required to achieve the air quality standard at the \( i^{th} \) receptor. \( X_j^{\text{Ambient}} \) denotes the number of tons of emissions to be removed under ambient strategy from \( j^{th} \) source.

This is equivalent to minimizing the following Lagrangian:

\[
\begin{align*}
\text{Min} & \quad \sum_{j=1}^{m} C_j(X_j^{\text{Ambient}}) + \sum_{i=1}^{n} \lambda_i \left( \sum_{j=1}^{m} (E_i - a_{ij} X_j^{\text{Ambient}}) \right)
\end{align*}
\]  

(4)

where, \( \lambda_i \) denotes the Lagrangian multiplier.

Many models in economics are naturally formulated as optimization problems with inequality constraints. However, there are circumstances under which problems can be reduced to optimization problems with only equality constraints. When emission control cost \( (C) \) is an increasing function of single constraint \( (X) \), a cost-minimization problem in this study can be reduced to optimization problem with only equality constraints. The FOCs for this problem are:

\[
MC_j(X_j^{\text{Ambient}}) = \sum_{i=1}^{n} \lambda_i a_{ij}, \quad j = 1, \ldots, m
\]  

(5)
The equation above shows that the marginal control cost for the $j^{th}$ source, $MC_j(X_j^{\text{Ambient}})$, should be equal to the sum of the transfer coefficients weighted by Lagrangian multipliers. Here, the Lagrangian multipliers reflect the changes in total control costs due to changes in the ambient air quality control level at site $i$. The total control costs of meeting ambient air quality constraints would be minimized if each source controls such that its marginal control cost is equal to its contribution to the total control costs of meeting the ambient air quality control levels. APS will achieve the social optimum if:

$$\sum_{i=1}^{n} MB_{ij}(X_j^{\text{Optimal}}) = MC_j(X_j^{\text{Ambient}}) = \sum_{j=1}^{n} \lambda_i a_{ij}, \quad j = 1, \ldots, m$$

That is, if the $E_i$ are set optimally, and if the transfer coefficient approach is correct, then this method will achieve the social optimum. If equation (6) does not hold, APS will not achieve the socially optimal level of control. However, it still minimizes control costs for society to meet the given ambient standards. The implementation of this system requires that transfer coefficients ($a_{ij}$) be identified, which is very difficult and costly. In many air quality control regions, such as the San Joaquin Valley, transfer coefficients are unavailable.

2. Uniform Marketable Permit System (UMPS)

UMPS does not require information about the transfer coefficients. It
minimizes the total control costs of emission reductions, but it does not necessarily meet the ambient standard at all receptors. This system can be represented as:

\[
\min \sum_{j=1}^{m} C_j(X_j^{\text{Emission}}) \\
\text{s.t.} \sum_{j=1}^{m} X_j^{\text{Emission}} \geq E
\]  

(7)

where, \(X_j^{\text{Emission}}\) indicates the emission reductions from \(j^{th}\) source. \(E\) is the total emission reduction from all sources needed to achieve the standard.

This is equivalent to minimizing the following Lagrangian:

\[
\sum_{j=1}^{m} C_j(X_j^{\text{Emission}}) + \lambda (E - \sum_{j=1}^{m} X_j^{\text{Emission}}), \ j = 1, \ldots, m
\]  

(8)

From the FOCs, the solution satisfies:

\[
MC_j(X_j^{\text{Emission}}) = \lambda
\]  

(9)

It can minimize the total control costs of achieving ambient standards if:

\[
\sum_{j=1}^{m} \lambda_i a_{ij} = MC_j(X_j^{\text{Ambient}}) = MC_j(X_j^{\text{Emission}}) = \lambda
\]  

\(j = 1, \ldots, m\)

(10)

It means that the marginal effect of one more unit of emissions is the same on all receptors, regardless of where that unit is produced. If these
conditions do not hold, as is the usual case, then the emission strategy
does not meet the ambient standard at all receptors and hot spot
problems occur. Neither APS nor UMPS may be an appropriate emission
control policy for the San Joaquin Valley. The Valley has not yet
identified the transfer coefficients necessary for APS. UMPS can be
implemented which minimizes the total control costs of emission
reductions, but some receptors could experience air quality worse than
the required standards in the Valley.

3. Localized Marketable Permit System (LMPS)

Localized marketable permit system would be more appropriate to
ensure that no receptors violate a required air quality and yet will require
lower compliance costs than CAC approach. The stationary sources in
each local area are considered to contribute equally to the air quality in
the Valley. LMPS can be represented as:

$$\text{Min} \sum_{j=1}^{S} \sum_{k=1}^{K_j} C_k^j(X_k^{j,\text{local}})$$

$$s.t. \sum_{k=1}^{M_r} X_k^{r,\text{local}} \geq E_r, \ r = 1, \cdots, 8$$ (11)

where,

$C_k^j$: total emission control cost for $k^{th}$ source in $r^{th}$ local area, $k = 1, \cdots, M_r$, $r = 1, \cdots, 8$.

$X_k^{r,\text{local}}$: the tons of ROG emission to be removed in $r^{th}$ region by the
$k^{th}$ source under LMPS.
$M_r$: number of sources in area $r$.

$E_r$: the total tons of ROG emission to be removed in area $r$.

The objective of this system is to minimize the total control costs to the stationary sources on the condition that the total ROG emissions for each local area ($r$) is reduced to the level ($E_r$) that is necessary to attain a proposed air quality in that area. Unlike CAC, the stationary sources in each area are allowed to trade freely their emission permits. Sources with higher control costs buy emission permits from sources with lower control costs; thus, total control cost to the stationary sources to reduce ROG emissions is smaller than it would be without such trading of emission permits.

III. Data and Scenarios

The San Joaquin Valley of California consists of eight counties and is approximately 350 miles in length and 50 miles in width. About 3.5 million people live in this Valley with a climate of hot summers and rainy winters. The Valley is a major agricultural production region and is also the second worst air quality region in California. Air quality in most of the counties in the San Joaquin Valley is much worse than the current ambient air quality standards. For each day, over 600 tons of ROG are emitted into the air in the Valley.\(^6\) Sixty percent of ROG emissions is

\(^6\) California Air Resource Board (1993).
from stationary sources. Other thirty percent of ROG emissions comes from mobile sources. The major stationary sources of ROG in the San Joaquin Valley are the petroleum refining and distribution industry. Table 1 details the stationary sources and their ROG emission per day.

In the San Joaquin Valley, the stationary sources are clustered into a few cities within which emissions can be considered to have the same impact on the air quality. Kern and Fresno counties alone comprise 85% of ROG emissions stationary sources in the Valley. Table 2 details the distribution of ROG emitting stationary sources among eight counties in the San Joaquin Valley. Of the hundreds of plants in the Valley, 97 large plants with 250 sources account for more than 95% of the total ROG emissions. The 97 ROG emitting plants are analyzed in this study to illustrate the costs of controlling ROG emissions in the San Joaquin Valley.

The air quality in San Joaquin Valley is reasonably independent from
### Table 2: Distribution of Stationary Sources in the San Joaquin Valley

<table>
<thead>
<tr>
<th>Name of Counties</th>
<th>Number of ROG Stationary Sources</th>
<th>Percentage Share of Total ROG Emission in San Joaquin Valley</th>
<th>Major Cities in Which Stationary Sources Locate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kern</td>
<td>169</td>
<td>80%</td>
<td>Bakersfield</td>
</tr>
<tr>
<td>Fresno</td>
<td>24</td>
<td>5%</td>
<td>Fresno</td>
</tr>
<tr>
<td>San Joaquin</td>
<td>25</td>
<td>3%</td>
<td>Stockton</td>
</tr>
<tr>
<td>Stanislaus</td>
<td>12</td>
<td>2%</td>
<td>Modesto</td>
</tr>
<tr>
<td>Merced</td>
<td>6</td>
<td>2%</td>
<td>Merced</td>
</tr>
<tr>
<td>Madera</td>
<td>3</td>
<td>5%</td>
<td>Madera</td>
</tr>
<tr>
<td>Tulare</td>
<td>3</td>
<td>3%</td>
<td>Tulare</td>
</tr>
<tr>
<td>Kings</td>
<td>8</td>
<td>0.3%</td>
<td>Hanford</td>
</tr>
</tbody>
</table>

Pollution sources in the San Francisco areas because wind blows from the San Francisco bay to Sacramento Valley and then to Nevada. It is also protected from pollution sources in the Los Angeles areas due to the Tehachapi mountains that blocks emission from transferring over to the San Joaquin Valley. Therefore, local stationary and mobile sources are responsible for the air quality in the Valley.

1. Control Cost Data

Two general approaches for controlling further emissions from stationary sources are based on the smokestack emission control technologies. One approach requires the installation of secondary control equipment, which is comparable to existing equipment. This approach could reduce further emissions as long as secondary control equipment provides additional emission reductions; however, it would be expensive.
to employ additional control equipment to reduce emissions further since a large part of the control cost is capital and installation cost. The other approach achieves a reduction in ROG emissions by increasing the destruction efficiencies of existing control equipment. The advantage of this approach is that it would be cheaper than the former because it only increases operating costs. However, the benefit to be realized by this approach is limited because most sources operate their control equipment near their maximum efficiencies.\(^7\)

Observing the methods used by other studies, this study assumes that pollution control treatments can be applied in sequence when developing ROG emission control costs. For example, an incinerator of any size could control inlet gases with a maximum efficiency of approximately 90\%.\(^8\) If we need to control additional emissions, we can sequentially install additional incinerators to control outlet gases from the initial incinerator. If an incineration methods with a 90\% efficiency is applied initially, and one additional incinerator with same efficiency is applied again, then the incinerators will collectively yield a 99\% control level. Therefore, the marginal control cost of achieving an additional 9\% control is measured by the cost of an additional incinerator.\(^9\)

We first assume that the current emissions of a source with no further control is \( E \), and let \( a \) be the efficiency of a currently available control technology. If, at the initial stage, an emission control device can control \( aE \), and at the second stage, an additional device can reduce emissions of \( a(1-a)E \), and at the third stage, the third device can further reduce

\(^9\) Kim (1994).
\( a(1-a)^2 E \), the total emission reductions \((X)\) with \(n\) control devices in a row are:

\[
X = aE + a(1-a)E + a(1-a)^2E + \cdots + a(1-a)^{n-1}E
= E(1-(1-a)^n)
\] (12)

The total control costs \((TC)\) would be sum of the costs of an individual device \((K)\).

\[
TC = n \cdot K
\] (13)

From (12) we can invert \(n\) as a function of \(X\).

\[
N = \frac{\ln \left(1-X/E\right)}{\ln (1-a)}
\] (14)

By substituting (14) into (13), the functional relationship between the total control cost \((TC)\) and the emission control level \((X)\) can be specified as:

\[
TC = K \frac{\ln (1-X/E)}{\ln (1-a)}
\] (15)

The ROG control cost function for each source can be estimated through the application of equation (15). Subsequently the ROG control cost functions for each sources were inserted into the mathematical programming model designed to allow emission permit trades among sources in the San Joaquin Valley.
Developing emission control cost functions for each source requires the data for ROG emission from stationary sources, types of control devices in place on the sources, their control efficiencies, and the costs of installing and operating the equipment. Information about stationary sources and their emissions was obtained from the California Air Resource Boards Emission Data System,\(^{10}\) while the types of control measures employed by the stationary sources measures and their costs were provided by the San Joaquin Valley Unified Air Pollution Control District.\(^{11}\) It is, however, difficult to measure accurately the cost of controlling amounts exceeding current levels unless plants identify their choices of alternative methods with their corresponding control costs.

2. ROG Emission Control Scenarios

In this study, three different ROG emission control policies are analyzed in the San Joaquin Valley: ① Command and Control (CAC) policy represented by uniform percentage reductions in emissions, ② Uniform Marketable Permit System (UMPS) in which all stationary sources in the Valley freely trade their ROG emission permits by one-to-one basis, and ③ Localized Marketable Permit System (LMPS) that allows one-to-one permits trading only for stationary sources locate within each county. Control costs associated with ROG emission reductions of 25%, 50%, 75%, and 90% under the three different control policies were applied to stationary sources to estimate cost savings associated with marketable permit systems.

\(^{10}\) California Air Resource Board (1992a, 1992b).
\(^{11}\) SJVUAPCD (1991).
The state policies directed at reducing ROG and emissions from stationary sources in the San Joaquin Valley have been primarily based on emission standards supplemented by an emission permit system, while the policy directed at reducing emissions from mobile sources focuses on controlling ozone through emission standards alone. The current ROG control policies for stationary sources, however, uses emission trading in a limited way and thus is less cost-effective than the case when emission permits are freely traded. The cost savings indicated in this study represent the differences between the costs of the marketable permit systems and those of CAC. Thus, they oversstate the advantages of the marketable permit systems relative to the current policy.

IV. Empirical Results

The emission control costs increases at the increasing rate as percentage of ROG emission reductions become greater, which reflects that controlling further emissions becomes more difficult and costly. <Table 3> details the emission control costs associated with the three different emission control policies in the San Joaquin Valley. The cost of controlling ROG emissions through the use of market incentive-based systems is much lower than CAC. The cost savings stem from the fact that each stationary sources are allowed to trade their emission permits. However, as higher ROG emission reductions were imposed on the stationary sources, the possibility of trading permits was reduced and this resulted in proportionally smaller cost savings. In the Valley, the major
(Table 3) ROG Emission Control Costs
in the San Joaquin Valley (in Million $)

<table>
<thead>
<tr>
<th>ROG Emission Control Policies</th>
<th>ROG Emission Controls in Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25%</td>
</tr>
<tr>
<td>CAC</td>
<td>$6.81</td>
</tr>
<tr>
<td>UMPS</td>
<td>$4.18</td>
</tr>
<tr>
<td>LMPS</td>
<td>$4.26</td>
</tr>
</tbody>
</table>

stationary sources emitting ROG are those involved in petroleum processing, storage, and transfer, and the control costs for controlling ROG in this industry are generally lower than other industries.\(^{12}\)

The total emission control costs associated with the CAC policy represent the highest costs of ROG emission reductions because it excludes any possibility of trading of emission permits. Under CAC policy, the costs of controlling emissions by county are not always directly proportional to the volume of emissions produced within that county. For example, Kern county incurs 60% of the total ROG control costs which is relatively low when one considers the actual volume of its ROG emissions, which is 80% of total ROG emissions in the San Joaquin Valley. The primary sources of Kern county’s emissions are engaged in petroleum, processing, storage, and transfer, which enjoy lower emission control costs. Conversely, Fresno county, which is responsible for only 5% of the total ROG emissions in the Valley, incurs 20% of the total ROG emission control costs. Its share of the total ROG control cost is disproportionary high because the ROG is produced primarily by sanitary

\(^{12}\) Kim (1994).
landfill and waste management. The shares of the total control costs for other counties are proportional to their contribution to the total emission in the San Joaquin Valley. Table 4 details the distribution of emission control costs for each county in the San Joaquin valley. Under CAC, the percentage share of the total control costs for each county is constant over the range of ROG emission reductions considered in this study.

UMPS minimizes the total control costs of ROG emission reduction in the San Joaquin Valley, but it does not necessarily guarantee that all receptors meet a required air quality. Since UMPS does not consider each sources different contribution to the same receptors, hot spots can be

---

created by one-to-one permit trading among them. If UMPS is applied to a wide region where sources are widely distributed, hot spots can be easily created and their problems might be serious. In the San Joaquin Valley, although stationary sources are clustered in a few major cities, they still be engaged in trading of their permits across cities with long distances. Under UMPS, hot spots are likely to be created in San Joaquin, Fresno, Madera, Stanislaus, and Merced counties. Because San Joaquin county locates further away from other counties in the Valley and its sources have relatively higher emission control cost, the county experiences more serious hot spot problems than other counties as a result of buying more permits based on one-to-one trading. 〈Table 5〉 displays the resulting ROG emission reductions in each county under UMPS.

LMPS divided the San Joaquin Valley into eight local areas by county. The stationary sources in each area are considered to contribute equally
to the air quality in the Valley. The objective of this system is to minimize the total control costs to the stationary sources on the condition that the total ROG emissions for each local area is reduced to the level that is necessary to attain a required air quality in that area. The stationary sources in each area are allowed to trade freely their emission permits. The total control cost to the stationary sources to reduce ROG is smaller than it would be without such trading of emission permits. Stationary sources are densely clustered in Kern county, which is responsible for 80% of the ROG emissions in the Valley. LMPS can result in significant cost savings if stationary sources in Kern county are allowed to freely trade their emission permits. Conversely, counties such as Madera, Merced, and Kings will not realized significant cost savings if LMPS is instituted because they have few stationary sources. LMPS applies to the San Joaquin Valley shows that the total control cost is slightly higher than UMPS and also prevent hot spots from being created. Since stationary sources are clustered in a few counties in the San Joaquin Valley, LMPS allows most of trading of emission permits among sources. Therefore, the cost-effectiveness of LMPS is close to that of UMPS in which sources freely trade their emission permits among sources within a county and across counties as well. On the other hand, since LMPS do not allow trading of emission permits across counties, the possibility of hot spots is prevented.

V. Conclusion

This study analyzed the ROG control costs of stationary sources in the
San Joaquin Valley of California. Marketable permit systems are more cost-effective in meeting a required air quality standard than CAC in the Valley. UMPS minimizes the control cost to reduce the total ROG emission, but some counties could experience air quality worse than other counties if one-to-one permits trading is allowed. LMPS would be more appropriate to ensure that no counties violate a required air quality and yet will require lower compliance costs than CAC approaches.

Despite our best efforts, the ROG emission control costs estimated in this study are subjected to many uncertainties and measurement errors. The cost functions of emission controls from stationary sources used in this study have some weaknesses. It is assumed that stationary sources apply the same control measures to reduce emission further. Alternatively, sources could use cleaner fuels, change production processes, or install new control equipment with higher control efficiencies, rather than installing the same device in sequence. This study does not allow for these possible choices; thus we probably overestimate control costs for ROG emission reductions. This study focuses only on ROG emitting stationary sources. If mobile sources were to included and allowed to trade emission permits across stationary and mobile sources, this would result in further cost savings of emission control. This study is likely to overestimate the true control costs because most factors provide upward bias to control cost; however, the magnitude of overestimation cannot be measured accurately.
© References ©


11. Maloney, M. T. and B. Yandle, “Estimation of the Cost of Air Pollution Control
The Cost-effectiveness of Alternative Emission Control Policies in the San Joaquin Valley of California


ABSTRACT

San Joaquin Valley의 Reactive Organic Gas 배출저감
정책수단의 비용효과성 분석

김홍진・조용성

동 연구는 미국 캘리포니아주 San Joaquin Valley의 고정오염원들로부터 발생되는 ROG(Reactive Organic Gases) 배출량을 저감하기 위하여 명령통제방식(CAC)과 경제적 유인제도를 적용할 경우의 비용효과성을 비교 분석하였다. 경제적 유인 제도로서는 UMPS(uniform marketable permit system)와 LMPS(localized marketable permit system) 배출권거래제도를 적용하였다.

분석결과 배출권거래제도(UMPS, LMPS)를 이용한 ROG 배출량 저감이 명령통 제방식보다 비용이 적게 드는 것으로 나타났다. 한편, one-to-one permits trading 이 허용되는 UMPS의 경우에는 일부 특정 지역에 대한 환경침이 악화되는 결과를 초래하는 경우가 발생하여, 궁극적으로 San Joaquin Valley의 ROG 배출량 저감을 위해서는 UMPS 방식의 배출권거래제도 도입이 보다 바람직한 것으로 나타났다.