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## **Effect of Energy Efficiency Standards on Natural Gas Prices**

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## **EXECUTIVE SUMMARY**

Requiring home appliances to meet fuel efficiency standards can reduce the fuel usage, fuel price, and the life-cycle cost of these appliances (Meyers 2005). Although this seems to be an unambiguous benefit to society, it is sometimes asserted, among other things, that the reduction in consumers' expenditures is obtained at the cost of reductions in the profit of fuel producers and owners of mineral rights and is thus a transfer from one sector of the economy to another, rather than a net benefit to society as a whole (Wiser 2005). In an attempt to resolve this question, we estimate the magnitude of the effects of a standard on the primary sectors affected by the standard and determine how much of the benefits are transfers from other sectors.

Modeling studies generally confirm the intuition that reductions in demand for natural gas will result in reductions in its price as seen at the wellhead (Wiser 2007). The magnitude of the effect on price relative to the demand reduction, and the mechanism through which it occurs, is less well established.

Revenue from the sale of natural gas at the wellhead must cover the cost of production, including the physical operations of exploration, drilling, and development of wells. It must also cover significant payments to land owners for the right to explore and extract the gas, as well as tax payments to government entities at the Federal, State, and local levels. It has been estimated that the Federal government collects, as taxes or lease payments, 40-50 percent of the revenue from natural gas extracted from Federal Offshore lands in the Gulf of Mexico (GAO 2007). The same report provided estimates that the total government share of revenue from the sale of gas produced in the states of Colorado, Wyoming, Texas, Oklahoma, California, and Louisiana are between 50 and 53 percent. The bonus payments, royalties, and taxes that make up this revenue are generally dependent on the value, volume, and price of gas produced. Any reduction in price, volume, or both will therefore directly affect the amount collected. To the extent that there is no offsetting cost savings within the government, reduced tax revenues must be made up by increased rates or additional taxes on other sectors.

Bonuses, rents, and royalties are also paid to private landowners for the right to explore and produce gas underlying their land. The value of those rights is a function of the value of the gas that can be extracted. Reductions in the price of gas will therefore reduce the value of the mineral rights, representing a capital loss to the landowner.<sup>1</sup>

Natural gas producers make their investment decisions on the basis of profitability of a proposed project. Expected price, demand, and cost of production are the primary factors that determine whether a project will be profitable and therefore undertaken. An unexpected price decline could, therefore, change future decisions and also the profitability of projects already undertaken.

If gas producers are able to include the effects of forthcoming standards into the forecasts of demand and price used to make their investment decisions, the introduction of a standard should have no effect on the profitability of their investments. Reduced demand may result in lower production volumes and prices but, as long as investments are willingly made in recognition of these effects, producers' returns cannot be said to be adversely affected by the standard. If the reduced demand results in fewer opportunities for investment in the natural gas sector, capital can be shifted to other sectors.

Even if one assumes that investors could not foresee the effects of the standards, only investments made prior to the introduction of the standard would be adversely affected. Investment decisions made after the standard became known would have been made with full knowledge of the standard's effect, including that of any excess capacity resulting from overinvestment prior to introduction of the standard.<sup>2</sup>

The analysis presented in this study used the National Energy Modeling System (NEMS) to estimate the effects of a recently proposed water heater standard. The results indicate that, over the 20 years from 2015 to 2035, the introduction of the standard leads to a \$48.9 billion benefit to consumers of gas and electricity. Of that benefit, \$9.8 billion represents a transfer from taxpayers or landowners. Over the same period, revenue from gas production declines by \$21.6 billion. Approximately \$7.1 billion of that reduction represents lower royalty or tax revenue to Federal, State, or local governments, and \$2.7

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<sup>1</sup> Where the rights have already been sold, the loss will be realized to the extent that the payment is tied to the price of gas. Where the rights have not been sold, the loss will be unrealized.

<sup>2</sup> Where investments are made in stages, later-stage investments made after the standard became known might be adversely affected to the extent that the schedule of investment could not be modified to reflect the new market conditions.

billion results from lower royalty payments to private landowners. Approximately \$1.9 billion of the reduction in revenue is associated with production from reserves created prior to 2010 and thus could possibly represent a reduction in producer profit. NEMS also estimates that about 2,000 fewer gas wells would be required over the 20-year period.



## 1 INTRODUCTION

### 1.1 Energy Efficiency Standards

A primary justification for the establishment of energy efficiency standards for home appliances is the existence of information deficiencies and externalities in the market for appliances. For example, when a long-term homeowner purchases a new gas-fired water heater, she will maximize the value of her purchase by comparing the life-cycle cost of ownership of available units, including both total installed cost—purchase price plus installation costs—and operating cost in the calculus. Choice of the appliance with the lowest life-cycle costs leads to the most economically efficient balance between capital cost and fuel cost. However, if the purchaser’s expected period of ownership is shorter than the useful life of the appliance, or the purchaser does not pay for the fuel used by the appliance, as is often the case with rental property, fuel cost will be external to her costs, biasing her decision toward spending less on fuel efficiency and resulting in the purchase of an appliance with greater than optimal fuel usage. By imposing an efficiency standard on appliances, less efficient appliances are made unavailable, precluding less efficient purchases and reducing fuel usage.

The reduction in fuel demanded by residential users affects the total demand for such fuels as natural gas, for example.<sup>3</sup> Reduced demand implies that residential customers are willing to purchase less gas at each price level. That is, the demand curve, labeled  $D_0$  in Figure 1, shifts to the left to  $D_1$ . If there is no change in the supply function, the supply curve will intersect the demand curve at a lower price.

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<sup>3</sup> “Over the long term, appliance efficiency gains and improved housing construction have resulted in a significant decrease in the volume of natural gas used by households in the United States, with per customer consumption falling in 16 out of the past 19 years. On a weather-adjusted basis, residential consumption over the 19-year period fell from 95 thousand cubic feet (Mcf) per customer in 1990 to 74 Mcf in 2009, or 22 percent.” (EIA 2009).

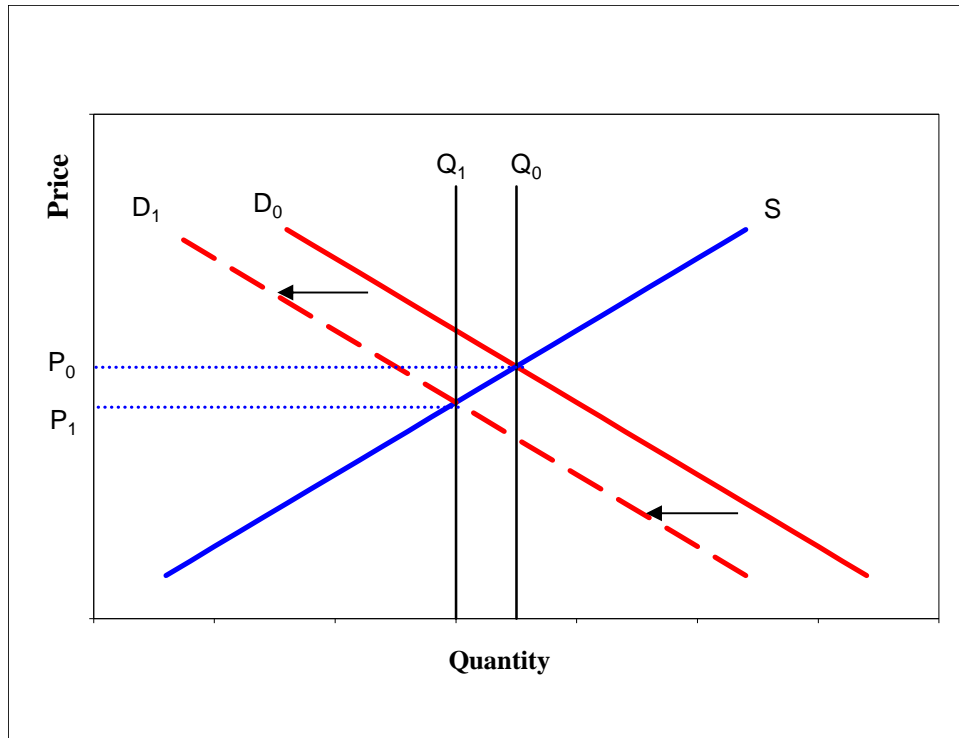


Figure 1. Supply and Demand Curves

Residential demand is only one component of the total demand for natural gas. It is possible that total demand will decline very little if demand in other sectors increases substantially in response to a decline in the price.<sup>4</sup>

If demand does decrease, modeling studies generally confirm the intuition that reductions in demand for natural gas will result in reductions in its price as seen at the wellhead (Wiser 2007). The magnitude of the effect on price relative to the demand reduction, and the mechanism through which it occurs, is less well established. This report attempts to quantify the potential effects of reduced demand for natural gas in the residential sector, in response to the implementation of an energy efficiency standard for water heaters.

## 1.2 Overview of the Natural Gas Sector

### 1.2.1 Physical Characteristics

Natural gas is extracted from underground geological formations either by itself or in association with crude oil.<sup>5</sup> These formations, or fields, are distributed widely on land

<sup>4</sup> For a more extensive discussion of the effect of demand reductions on natural gas prices, see Wiser 2005.

and offshore. The differing characteristics and locations of these gas-bearing formations result in a range of costs of production. Some formations are shallow, close to centers of consumption, and yield their gas easily. Others are deeper, far from population centers, or give up their gas only after complex underground development—characteristics that increase drilling, development, and transportation costs. As the shallow, nearby formations are depleted, producers must turn to those requiring more extensive and costly development.

### ***1.2.2 Investment and Production Costs***

Before exploitation of a reservoir can begin, a producer must acquire from the landowner the right to explore and produce the gas and confirm, through surface and subsurface exploration, the presence of economically producible quantities of gas. Once the economics of production have been established, production wells are drilled and developed, and processing facilities are installed, along with pipelines connecting to established transmission and distribution systems. Natural gas production is capital intensive. The process of discovery and development of a new formation can require a number of years.

“The natural gas industry is well known to operate over very long timescales, not least because of the capital intensive nature of the infrastructure projects and the complexity of putting together the necessary operational and contractual arrangements throughout the whole gas chain. Although some small upstream projects can now be brought to market within a couple of years of discovery, the world’s gas giants inevitably take much longer when they are located far from the main markets.” (Lyle 2006)

“To meet future natural gas demand, producers must invest many billions of dollars annually. Industry must compete against other domestic investment options that produce higher returns as well as competing against potentially lower cost foreign investments. Exploration and production planning can be risky because market volatility, as recently experienced, can deny producers reasonable assurance that their investments will be rewarded. For example, over the past two years [2001-2003] prices have ranged from about \$2 per million cubic feet of natural gas to \$10 per million cubic feet. Prudent planning demands that producers average out

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<sup>5</sup> Approximately 90 percent of the gas produced in the lower 48 of the United States in 2008 was not associated with the production of oil. Of that, over 60 percent was produced from tight gas formations, gas shales, and coalbeds (EIA 2009).

prices over the long term to determine investments.” (National Petroleum Council 2003)

As these two excerpts indicate, the discovery and development of natural gas is not only costly but also quite risky. The American Petroleum Institute’s 2007 Joint Association Survey on Drilling Costs reports that in 2007 the “average cost per natural gas well was \$3.9 million” and that “Per-foot, natural gas expenditures averaged \$604” (API 2009). The EIA reports that the success rate of crude oil and natural gas exploratory wells was 66 percent in 2007(EIA 2009c).

Producers’ decisions to develop a particular gas field, often called a “play”, are based on an evaluation of the net present value (NPV) of the costs and revenues that will be generated by the play over its life (Kuuskraa 2008). The NPV method calculates the difference between the present value of all revenues generated by the project and the present value of all capital and operating costs required by the project.<sup>6</sup> If the difference, the present value of revenue net of the present value of cost, is positive, the investment will be profitable (Brealey et al, 2000).

The present value of expenditures and revenues are simply their future values discounted, using an appropriate interest rate, from the time of expenditure or receipt back to the present. As the present value is sensitive to both the magnitude of the expenditures and revenues and their timing, the NPV of a project can shift from positive to negative if its expected revenues decline or are delayed.

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<sup>6</sup> Multistage projects with several decision points may require more complex analysis. However, the NPV of the project or subproject remains the basis for evaluating its value. NEMS uses the NPV, which it calls a Discounted Cash Flow (DCF), method to determine whether gas resources are developed.

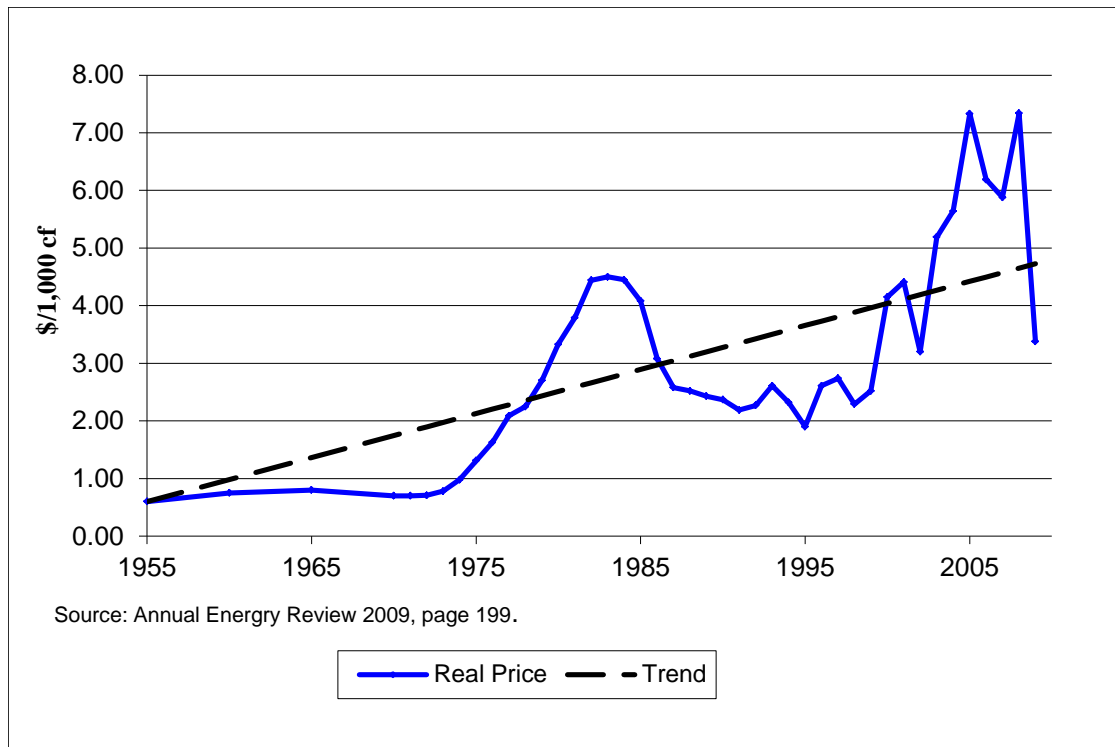


Figure 2. Natural Gas Wellhead Price

That is not to say that expected revenues are easily forecast. As shown in Figure 2, there has been substantial fluctuation in the wellhead price of natural gas over the last fifty years. Obviously, investment decisions based on forecast prices must recognize the substantial risk of future price movements.

### 1.2.3 Revenue Chain

In general, natural gas producers find, develop, extract, and process natural gas, selling it to gas marketers or distributors. They receive the wellhead price for the gas at the delivery point and from that revenue pay exploration, development, and production costs, as well as taxes, rents, and royalties. Exploration, development, and production costs are either internal to the producer or paid to subcontractors. Taxes are paid to Federal, State, and local governments and include income, severance, and property taxes, as well as environmental fees. Rents and royalties are paid to landowners for the right to find and extract the gas.<sup>7</sup>

## 1.3 Prices, Bonuses, Rents and Royalties, and Taxes

### 1.3.1 Prices

<sup>7</sup> Although mineral rights are not necessarily held by the owner of the land, that is most often the case in the United States, and alternate ownership does not materially affect our analysis.

The price of a resource such as natural gas reflects the interaction of its demand and supply curves. The demand curve is simply a schedule of the quantity of gas consumers are willing to purchase at any particular price. (See Figure 1.) The supply curve is likewise a schedule of the quantity of gas producers are willing to produce and sell at each price level. Where the production sector is competitive, a producer will be willing to extract a resource at a cost equal to “the supply prices of the economic inputs (plant, equipment, fuel, labour) employed in its production”, with the supply price being “the minimum price that will entice supply of an economic input” (Watkins 2001). That is, natural gas producers will find, develop, produce, and sell gas when the discounted value of the anticipated revenue generated by its sale is greater than the discounted value of the exploration, development, and operating costs, including the cost of capital that must be invested to produce the gas. From the producers’ point of view, the cost of obtaining the right to extract gas, either from the landowners or their intermediary, is one of the costs of producing gas. Where the production sector is competitive, producers will be willing to pay the landowners the difference between the anticipated selling price of the extracted gas and their total cost of production, including an adequate return on invested capital. That is, they will be willing to pay the landowners the sum of the scarcity and Ricardian rents described below.<sup>8</sup>

When considering an offer from a producer, a landowner faces the choice of selling now or waiting for a “better” future offer. If he sells now he can invest the proceeds at the prevailing interest rate. In order to provide a higher present value than the current offer, any future “better” offer must be greater than the value of the current offer plus interest earned over the intervening period. If the owner believes he can realize a higher value by selling later, he will not accept the offer and will wait for a better offer to materialize. That is, if the owner believes the price producers are willing to pay for his right will increase at a rate less than the prevailing interest rate, he will be willing to sell. Conversely, if he believes the price will increase at a rate greater than the interest rate, he

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<sup>8</sup> This is somewhat of an oversimplification, as it does not specifically acknowledge the value of risk taken on by producers or intermediaries.

will not sell. This is simply a restatement of Hotelling's rule<sup>9</sup> recognizing the way rights are actually sold.

### ***1.3.2 Economic Rents***

#### **1.3.2.1 Scarcity Rent**

Hotelling's model of exhaustible resource pricing, developed in 1931, remains the basis for much of the discussion on the subject of scarcity rents. He showed that efficient exploitation of a resource is achieved when its price rises toward the price at exhaustion at the rate of interest. He also points out that, if production is costless, that price trajectory will result from the rational choices of resource owners (Slade et al 2010). The explanation is that, if resource values or rents are anticipated to increase faster than the interest rate, owners will hold their resources in anticipation of the higher prices. Reduced current supply will tend to raise current prices, and increasing potential future supply will tend to reduce future prices. If the value of the resource is anticipated to rise at a rate slower than the interest rate, owners will compete to sell their resources in the current market, reducing current prices, increasing future prices, and thus increasing the rate of increase.

That finding leads to the existence of an economic or scarcity rent associated with ownership of the resource. An economic rent is usually defined as the difference between price and cost of production. For example, a 2001 report evaluating Canadian tax and royalty policies defines economic rent as follows.

“An operable definition of economic rent is the profit over and above that necessary to obtain production from a project, a sort of superprofit. More technically, economic rent can be defined as the difference between market value of a commodity and the supply prices of the economic inputs (plant, equipment, fuel, labour) employed in its production. A supply price is the minimum price that will entice supply of an economic input.”  
(Watkins 2001)

Where production is costless, the economic rent is equal to the entire value of the resource, as illustrated in Figure 3. That is, the price of the commodity is due entirely to its scarcity rather than to its cost of production.

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<sup>9</sup> Hotelling showed that efficient extraction of an exhaustible resource required that the net price rise at the rate of interest (Hotelling, 1931).

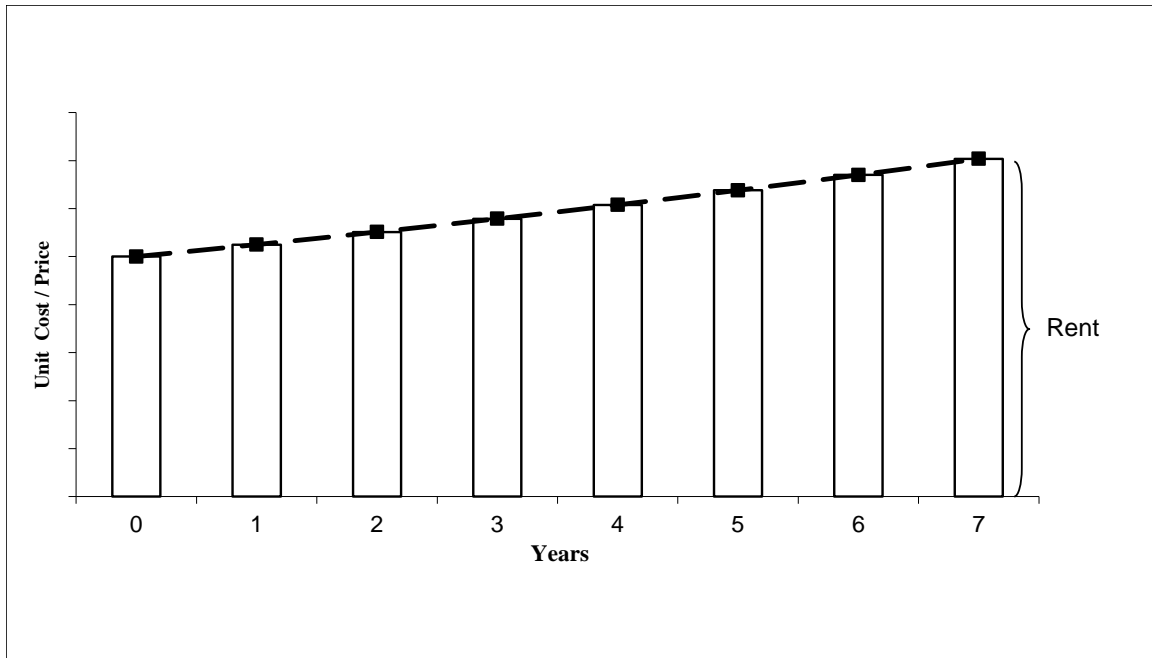


Figure 3. Economic Rents: Zero Production Cost

The price trajectory is not as simple if production is not costless. If the decision to exploit is controlled only by independent resource owners and the production sector is competitive, the rights owners' decisions will be based on the price of the commodity less the cost of production—the economic rent.<sup>10</sup> Competitiveness of the production sector ensures that the owner can find a firm willing to develop and produce a field as long as it can make a competitive return on capital invested. Thus, the value that is of concern to the resource owner is not the price of the resource but the difference between the price and cost of production. Figure 4 illustrates the case where the cost of production rises steadily over time, resulting in a steadily rising price.

<sup>10</sup> Production is here meant to include all activities required to bring a field into production as well as production operating costs.



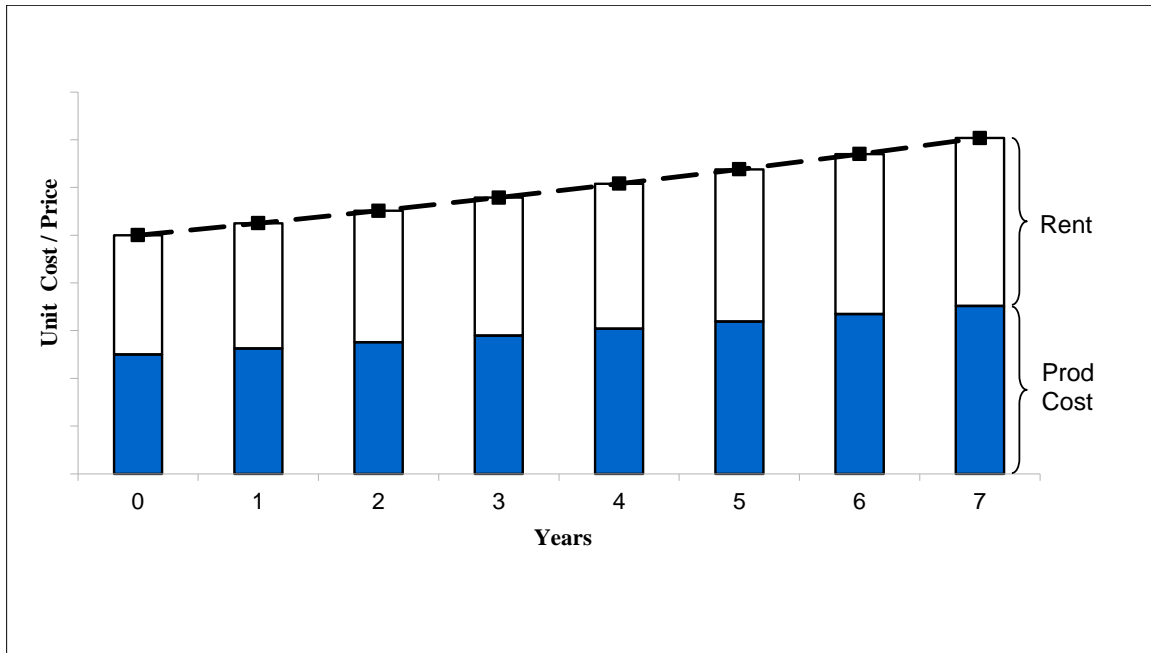


Figure 4. Economic Rents: No Taxes

### 1.3.2.2 Ricardian Rent

The above discussion assumes that all resources available at any point in time have the same cost of production. In actuality, natural gas, for example, will be produced from fields of differing costs with the market price being based on the cost of gas produced by the marginal field, or the field with the highest production cost.<sup>11</sup> This leads to a Ricardian rent associated with fields having lower production costs than the marginal field.<sup>12</sup> Figure 5 provides an illustration of the rents associated with fields of differing unit costs. The value of the total rent for each is simply the difference between the market price and the cost for each field. The “technical” component of the rent is the difference between the field’s unit cost and that of the marginal field, Field 1 in the illustration.

### 1.3.3 Ownership Limitations

<sup>11</sup> In reality, transportation limitations may result in numerous markets and associated marginal fields.

<sup>12</sup> Webster’s Revised Unabridged Dictionary (1913) defines Ricardian rent as follows:

(a) That portion of the produce of the earth paid to the landlord for the use of the “original and indestructible powers of the soil;” the excess of the return from a given piece of cultivated land over that from land of equal area at the “margin of cultivation.” Called also economic, or Ricardian, rent. Economic rent is due partly to differences of productivity, but chiefly to advantages of location; it is equivalent to ordinary or commercial rent less interest on improvements, and nearly equivalent to ground rent.

(b) Loosely, a return or profit from a differential advantage for production, as in the case of income or earnings due to rare natural gifts creating a natural monopoly.

In the United States, ownership of the right to extract mineral resources from beneath a parcel of land is usually held by the landowner. However, all the land overlying a gas-bearing reservoir is seldom in the ownership of a single entity, and small areas of the reservoir cannot be exploited without affecting a larger area. In the early days of petroleum exploitation in the United States, one could simply drill a well on a small parcel and extract as much of the gas from the reservoir as could be accessed from that well, including that portion overlain by neighboring properties (Libcap and Smith 2002). This “right of capture” rule no longer applies, and in most cases all landowners overlying a reservoir must be compensated for any gas extracted from an underlying reservoir.<sup>13</sup> This requires that all rights to exploit a reservoir be acquired, either by a producer or an intermediary (“landman”) before production can begin.<sup>14</sup> Obviously, this precludes each landowner from making a buy-hold decision completely independent of others overlying the same reservoir. However, the collective decision of landowners should follow the

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<sup>13</sup> Compensation to landowners usually takes the form of a one-time upfront payment, a bonus, or ongoing fixed rent, which may apply only until production begins, and a royalty equal to a percentage of the value of the gas produced.

<sup>14</sup> In some states a reluctant owner will be compelled to lease his land. In New York for example, "the DEC [Department of Environmental Conservation] approves the spacing unit that is proposed by a company, based on seismic, geologic, and reservoir engineering data provided to the Department. The property owner will receive a notification to participate in the public hearing process in which the spacing unit is reviewed. A gas company may then extend an offer to lease to parcels that are about to be integrated in a spacing unit. If the landowner declines a lease, then compulsory integration may occur after a notice and hearing." (Cornell University Cooperative Extension)

Hotelling rule described above.<sup>15</sup>

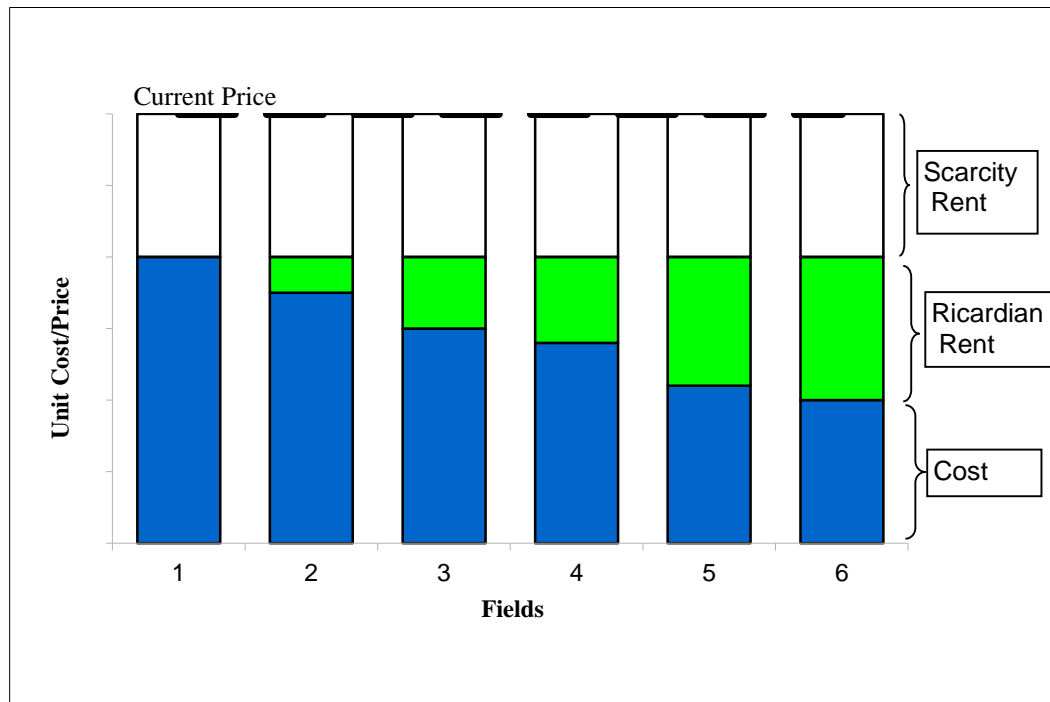


Figure 5. Ricardian Rent

### 1.3.4 Taxes

Competitiveness of the production sector ensures that producers will be unable to capture any portion of the economic rent.<sup>16</sup> However, as noted above, gas production is subject to taxation by a number of government entities. Local governments may impose property taxes based on the value of the extractable gas; States may impose severance taxes based on the volume or value of gas extracted; and the State and Federal governments may tax the profit of producers and the payment made by producers to landowners. These taxes capture a portion of the economic rent that would otherwise accrue to the landowner.<sup>17</sup>

<sup>15</sup> Often complex rules govern the extraction of gas. For example, the output of a well or group of wells may be limited to the rate that will not generate “waste”. Texas Natural Resources Code Sections 86.012, 86.041-043, 86.081-097.

<sup>16</sup> Producers can capture some portion of the rent by accepting more of the project risk. In that case they take on a financial role as well as the role of producer. For example, producers may purchase and hold mineral rights in anticipation of future needs, thus accepting the risk that demand and or price may decline before the resource is developed.

<sup>17</sup> If set higher than the economic rent, taxes may affect the supply function causing production to deviate from the optimal path.

In the presence of taxes, the payment producers will be willing to offer a landowner, illustrated in Figure 6, is the wellhead price less production costs and all taxes applied to producers. The landowner in turn will make his decision to accept or reject an offer based on the payment offered by producers net of taxes applied to that payment. In making a decision to accept or reject an offer, a landowner must have some estimate of the trajectory of demand, production costs, and tax policy.

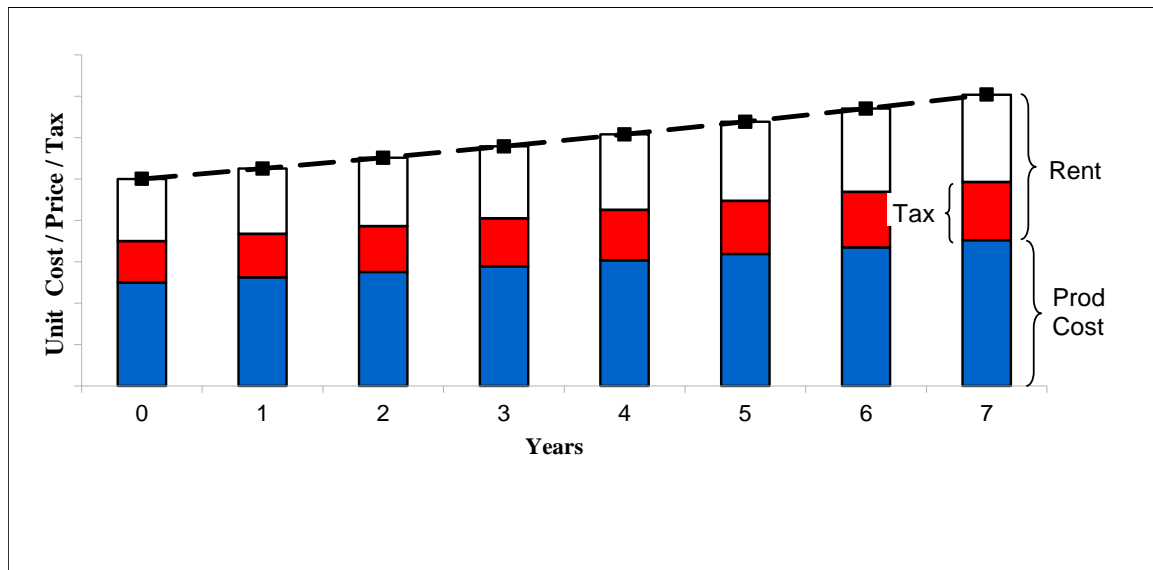


Figure 6. Economic Rents: With Taxes

### 1.3.5 State and Federal Ownership of Mineral Rights

The preceding discussion considers only the decisions of private landowners. In fact, a substantial portion of the natural gas produced in the United States is from lands owned by Federal or State governments. Historic Energy Information Administration (EIA) data indicate that 27 percent of natural gas produced in 2008 came from Federal onshore (16 percent) or offshore (11 percent) lands (EIA 2008). In addition, many states hold land on which gas is produced. Production from state lands is more difficult to identify but in 2008, at least 3 percent of the gas produced in the United States was produced from state lands (State Land Office data).

A governmental landowner interested only in maximization of revenue would base its decision to sell its mineral rights on the total revenue it would receive, including both payments from producers and taxes associated with production. However, a government's decisions are complicated by its interest in public policy and taxes on other

business sectors. For example, a government may accept lower payments from producers in order to stimulate development of the local natural gas sector or the local economy in general. These concessions can take the form of forbearance from taxes or reduced royalties or bonuses. The presence of governments as sellers in the market for extraction rights may therefore lead to unforeseeable movements in the market for extraction rights.

### ***1.3.6 Split of Revenue***

If producers, governments, and rights owners all had perfect information about geological conditions, prices, and the cost of production, competitive producers would be unable to capture any of the economic rent. Governments could set taxes to leave landowners only sufficient rent to elicit sale of their mineral rights. In reality, information about the ultimate productivity of a field, its production cost, and the price at which its gas will be sold is subject to substantial variation and uncertainty. As a result, and consistent with the discussion above, the economic rent available to government and landowners varies with each field, and royalty and tax regimes must be sufficiently flexible to capture as much of this rent as possible without discouraging profitable development. The combination of taxes, fees, royalties, and other payments to landowners is known as a “fiscal system” and determines what portion of the economic rent is captured by government and landowners.

Fiscal systems are complex and vary throughout the world depending upon the ownership of mineral rights, the political structure of the country, and the geologic characteristics of the resources within the country. In most countries all elements of the fiscal system are under the control of the government. In the United States, where mineral rights can be in private or public ownership, government entities control the tax portion of the system, but much of the compensation for mineral rights is determined by private commercial agreement. This substantially complicates the determination of the split of revenue between producers, government, and landowners because information about royalty payments to private landowners is not available on a systematic basis. Studies of fiscal systems in the United States indicate that the combined government-ownership share of revenue—taxes plus payments to landowners—is approximately 50 percent (Van Mears 2007:US GAO 2007). Information on the split between taxes and payments to owners is more variable and difficult to determine.

## **1.4 Summary**

In the United States, gas producers decide to develop and produce gas from a field based on the profitability of the “play”. If the present value of revenue from the gas that can be produced is greater than the present value of the total cost of production, including exploration and capital costs, then production will be profitable and will be undertaken. The economic rent associated with a play is the difference between the market price of the gas and the cost of production, including exploration, development, and a suitable return. The economic rent is shared among producers, governments, and landowners. Governments determine their share through the setting of taxes and fees. The landowners’ share is determined by negotiations between producers and landowners. Where government entities own mineral rights the distinction between compensation to landowners and taxes is blurred. Although each may accrue to a different division of government, their aggregate value is revenue to the government as a whole. As the owner of mineral rights, a government entity has the incentive to obtain maximum compensation for those rights. However, as a recipient of taxes from other sources, it also has an incentive to reduce its compensation in order to stimulate other economic activity.

## **2 EFFECTS OF ENERGY EFFICIENCY STANDARDS**

### **2.1 Potential Effects**

By limiting consumer choices, the imposition of a home appliance efficiency standard induces consumers to choose appliances that use less fuel but may be somewhat more expensive than the appliances that would be available in the absence of the standard. The ensuing reduction in demand for natural gas by residential customers will have effects throughout the economy, especially on producers and consumers of natural gas and substitute fuels. Following is a partial list of potential effects of reduced demand for natural gas in the residential sector.

- The volume of gas produced and sold may decline.
- The wellhead price of gas may decline.
- The aggregate profits of gas producers may decline.
- The profitability of specific projects may decline.
- Tax revenues from natural gas production may decline.
- Compensation to mineral rights holders may decline.

- Gas exploration and development activities may decline.
- The use of natural gas by other sectors may increase.
- In locations where total demand is declining, the price of natural gas delivered to residential consumers may increase if the lower demand impairs the gas distributors' ability to recover the cost of the fixed infrastructure.

## 2.2 Classification of Effects

### 2.2.1 *Changes in Social Welfare*

Appliance efficiency standards limit the characteristics of available appliances so that consumer choices will result in a more efficient mix of capital and operating expense. In the case of residential water heaters, homeowners will be induced to heat their water at a lower life-cycle cost, because they can choose only appliances that use fuel more efficiently. If the standard achieves that goal, expenditures on fuel by residential customers will decline, expenditures on water heaters will increase, and net expenditures on water heating will decline. The shift in expenditures from fuel to water heaters may require some shift in capital from the fuel (natural gas) sector to the appliance sector in order to accommodate the changes in demand.

Post-standard, residential customers pay less for heating water and are able to use the savings to purchase additional goods and services. The introduction of the standard is unambiguously beneficial, in the long run, to the consumers and also expands the total welfare in the economy by more efficient use of exhaustible resources, such as natural gas, and capital.<sup>18</sup>

Other consumers of natural gas—the commercial, industrial, and electricity generation sectors—will also benefit from any reduction in the price of natural gas resulting from the reduced residential demand. Their wealth will increase by the volume of gas they would have consumed in the absence of the standard multiplied by the reduction in price. They can use that incremental wealth to purchase other goods, including additional natural gas.

### 2.2.2 *Transfers*

Even where there is a net benefit to the economy, some sectors may be negatively affected by the imposition of a standard. The value of mineral rights will be directly affected by a decrease in the price of natural gas; the value of facilities devoted to the

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<sup>18</sup> This assumes that the standard is set at or near the optimal level. It is certainly possible that a very stringent standard could raise rather than lower life-cycle costs.

production of natural gas will also be negatively affected. If tax revenues from natural gas production or sales are diminished, they must be made up from tax rate increases in the natural gas or other sectors. These negative effects are effectively transfers from the harmed sector to benefited sectors and must be properly accounted for in order to determine the net effect on the economy.

#### **2.2.2.1 From Investors in Natural Gas Production Capacity**

If capital shifts smoothly from the natural gas sector to the appliance or other sectors, investors' portfolio of assets will change, but their return on investment will not be affected. Anticipating the shift in demand from fuel to appliances, investors direct more capital to the appliance sector and reduce investment in natural gas production assets. The result is an increase in the capital stock of the appliance sector and a decline in the capital stock of the natural gas sector, which occurs as the stock of natural gas assets depreciates and is not replaced.

If investors do not anticipate the shift in demand resulting from the standard and continue to increase the capital stock of the gas sector, its capital stock might well become greater than justified by the post-standard demand.<sup>19</sup> For example, the return on an investment that was justified by a gas price of \$10 may not be profitable at a lower price and, had the lower price been anticipated, the capital might have been shifted to another sector. More importantly, investments that yield a less than adequate return indicate a misallocation of capital, if higher yielding investment opportunities are not undertaken for lack of available funds.

If a standard is introduced in such a way that investors cannot anticipate its effects, and thus invest more in gas production capacity than ultimate demand justifies, their reduced profits should be considered to be a cost of obtaining the benefits received by consumers. That is, part of the benefit to consumers should be considered a transfer from natural gas investors rather than an increase in total wealth.

Assuming that the introduction of the standard was unexpected and its effect on demand could not have been anticipated by investors, the magnitude of the reduced profit can be conservatively approximated as the reduction in revenue generated by investments made

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<sup>19</sup> Even if investment in the sector stops, overcapacity may result if demand falls faster than the rate of depreciation of current production assets.



before the terms of standard became known.<sup>20</sup> Investments made after the announcement of the standard are made with full knowledge of the effect the standard, and any overcapacity in the sector resulting from the standard, may have on sales volume and price. If only profitable investments are undertaken, post-standard investments that are undertaken provide, by definition, an adequate return and are thus unaffected by the standard. That some investments that would have been made absent the standard are not made or deferred does not affect the profitability of the capital, if it can be shifted to other sectors.

While it is possible that an unanticipated standard could be introduced, the long-standing nature of the appliance standards program, the long lead time between announcement and promulgation of a standard, and ongoing communication with appliance manufacturers would make it unlikely that any standard could be introduced without the knowledge of all stakeholders. The magnitude of the price effects relative to historic fluctuations also makes it unlikely that the effect of standards could, on its own, materially affect producers' profits.

#### **2.2.2.2 From Owners of Mineral Rights**

Compensation to owners of mineral rights, including signing bonuses, rents, and royalties, are revenues that flow from consumers to owners of mineral rights whether they be private individuals, corporations, or governments. Bonus payments are fixed, one-time payments to the rights owner. Rents are fixed payments to the mineral right holder that usually cover the period between signing and beginning of production. Royalties are usually a fixed percentage of the value of the gas extracted.<sup>21</sup> Although the structure of compensation can vary substantially, all of these forms of compensation are indirectly, if not directly, tied to the value of the gas produced from the well or field. Bonus payments and rents are a part of the total compensation to the landowner, and producers are willing to pay higher compensation when prices are higher. A reduction in price will therefore result in a reduction in compensation to landowners. In addition,

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<sup>20</sup> This also assumes that operating costs associated with those investments are fixed.

<sup>21</sup> There has been substantial controversy surrounding the determination of the value of gas used to calculate the royalty. Specifically, the controversy is over what expenses are appropriately deducted from the value of the gas. See, for example, Brantland 2001.

reduced demand will delay the exploitation of a field and thus the compensation to the landowner.

### **2.2.2.3 From Other Tax Payers**

Taxes commonly applied to natural gas include severance taxes, usually based on the value of the gas produced, environmental fees, conservation fees, and property taxes on plant and equipment, as well as income taxes on compensation to mineral rights owners and the profit of producers. Revenue from all of these taxes may be reduced as a result of the introduction of a standard. In order to maintain the services supported by these taxes, the government entities receiving these revenues will have to either increase the rates of the existing taxes so that the gas produced generates the pre-standard revenue or increase taxes on other sectors to compensate for the loss in revenue from taxes associated with the natural gas sector. The loss of tax revenue is therefore a transfer from those who will pay increased taxes to consumers who benefit from the standard.

To the extent that taxes are reimbursement for services provided to the natural gas sector, any reduction in tax revenue could be considered a direct cost savings rather than a transfer. However, only where the tax is equal to the variable cost of the service would there be a fully compensating cost savings. Where much of the cost of the service is fixed, as in regulation of gas production, for example, the total cost of the service would be little affected by a small reduction in production volume. Support for the service would in that case have to be made up from higher rates or other sources. Much of the reduction in taxes resulting from the standard are therefore transfers from those who ultimately make up the shortfall in tax revenue.

## **3 QUANTIFICATION OF EFFECTS**

The economics of depletable resources can provide some qualitative insight into these effects. For example, Dale argues that, because the long-run average production cost of a finite resource increases as the resource is depleted, reductions in demand (i.e. rate of usage) delay depletion and therefore shift the supply curve downward (Dale 2006). It seems uncontroversial that, if average production cost increases as the resource is depleted, reducing the rate of depletion, all else remaining equal, will result in lower average production costs at any point in time. Dale concludes that the “downward shift in the supply curve lowers price for consumers but it also lowers producer costs, leaving

consumers better off and producers at least no worse off” (Dale 2006). The reduction in production costs results from decreased utilization of high cost resources and lower payments to rights owners. This conclusion seems correct, but provides little insight into the mechanism by which costs are reduced nor any method for quantifying the short-term effect on producers or the effects on other sectors.<sup>22</sup>

Quantification of the effects requires analysis of the interactions between all sectors of the energy economy. The National Energy Modeling System (NEMS) is particularly well suited for verification and quantification of these effects. The model output provides production, usage, and price information for all energy sources in the U.S. economy. Each year EIA provides reference case results from a model run based on its best assessment of input variables. The model is also available to users, allowing user-specific modifications to its input values.

Comparison of the results of a NEMS reference case with a case that includes the estimated demand changes that will be induced by the introduction of a standard can provide direct quantification of many of these effects. The effect on usage of natural gas and electricity by the residential sector is an input to the model. The model then generates the effect those changes induce in demand by the commercial, industrial, and electricity generation sectors and the prices to all sectors. NEMS also calculates production volumes, average wellhead prices, and annual reserve additions for each case, from which the effect on taxes, royalties, and producer profits can be indirectly estimated. The estimates generated in this study are based on a variant of the NEMS model, NEMS-BT,<sup>23</sup> used by the Lawrence Berkeley National Laboratory (LBNL). The magnitude of the energy decrement that would be required for NEMS-BT to produce stable results out of the range of numerical noise is larger than the highest efficiency standard under consideration. Therefore, we have estimated results using extrapolation from NEMS-BT

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<sup>22</sup> The short term is usually defined as “a period of time in which only some variables change or economic processes work” (Bannock et al 1987). In the context of natural gas production a more specific and useful definition of the short term is the life of a natural gas producing well, i.e. the period over which only operating costs but not investments in a well can be changed.

<sup>23</sup> DOE/EIA approves use of the name NEMS to describe only an official version of the model without any modification to code or data. Because this analysis entails some minor code modifications and the model is run under various policy scenarios that are variations on DOE/EIA assumptions, DOE refers to it by the name NEMS-BT. (BT is DOE’s Building Technologies Program, under whose aegis this work has been performed.) NEMS-BT was previously called NEMS-BRS.

runs with demand decrement inputs that were multiples of the estimated energy use reductions. The induced changes in relevant NEMS output variables were then determined by linear extrapolation from the results of these runs.

### **3.1 Calculating Effects**

#### ***3.1.1 Residential Consumers***

As the gas and electric usage of the residential sector is modified as a direct result of a standard, the appropriate method of calculating the standard's effect is unique to this sector. The standard-compliant appliances provide the same functions and amenities as the reference case appliances but at lower energy usage levels. The benefit to residential consumers is, therefore, simply the change in their expenditures for natural gas and electricity less the change in expenditure for the appliances. (Note that the difference in cost of the standard compliant and reference case appliances must be externally calculated and is not included in this study.)

#### ***3.1.2 Other Consumption Sectors***

For all other sectors, the appropriate measure of benefit is the change in expenditure required to purchase the quantities of gas and electricity that would have been used if no standard had been implemented but at the reduced prices resulting from standard implementation. This benefit amounts to the difference in price (standard – reference case) multiplied by the usage in the reference case. This calculation provides the amount of additional cash the consumers would have if they consumed the same amount of gas and electricity at the lower prices of the standard case.

#### ***3.1.3 Payments to Rights Owners***

Payments to rights owners are generally calculated as a percentage of wellhead value. Reduced demand and price for natural gas will therefore delay and reduce those payments. Although delay in payments reduces the value of the right, quantification of the reduction depends on the length of delay and the discount rate used in the calculation. Rather than attempting to estimate these values, we calculate the reduction in payments to rights owners on the basis of the price reduction only, ignoring the loss in value due to the delay in payment. The change in payments is thus calculated as the change in price multiplied by the volume of production in the reference case, which is in the absence of a standard. The aggregate owner/government share is relatively well established at

approximately 50 percent of wellhead revenue. The division of this revenue between rights owners and government varies by state and by ownership. Accurate determination of that division would require detailed analysis of each state's tax regime and require systematic information on payments to private rights owners. Such an analysis is beyond the scope of this report. Since our primary purpose is to show the magnitude of transfers, we assume, as a first approximation that the 50 percent ownership/government share is divided equally between payments to rights owners and tax payments to government. The owners' share is therefore calculated as 25 percent of wellhead revenue (average wellhead price times production volume).

The effect of the standard on payments to owners is calculated as the difference between calculated payments to owners in the standard case (owners' share multiplied by reference volume multiplied by standard price) minus that calculated in the reference case (owners' share multiplied by reference volume multiplied by reference price).

#### ***3.1.4 Tax Revenues***

Tax revenues are generally related to the volume or value of production. The effect of a standard on these streams can therefore be reasonably estimated as a percentage of wellhead revenue. As noted above, we assume that the tax share is 25 percent of wellhead revenue. The effect of the standard on tax revenues is calculated as the difference between calculated tax revenues in the standard case (government share multiplied by standard volume multiplied by standard price) case minus that calculated in the reference case (government share multiplied by reference volume multiplied by reference price).

#### ***3.1.5 Government-Private Owner Split***

As discussed above, government entities own a substantial portion of the land overlying natural gas reservoirs. In these areas the government receives both the owner's and government's share of the revenue. NEMS does not directly estimate the portion of gas produced from state and Federal lands, but historic production data for 2008 indicate that approximately 30 percent of the natural gas produced that year came from Federal or State lands (EIA 2008b).

#### ***3.1.6 Transmission and Distribution***

The transmission and distribution of natural gas is subject to Federal or State regulation. Under regulation, the revenue of the sector will, in the long term, be equal to sector costs plus a reasonable profit. While the efficiency of infrastructure investments may be adversely affected by the reduced demand associated with an unanticipated standard, tariff adjustments will eliminate any effect on long-term profits of the sector. The revenue of the transmission and distribution sector is calculated as the difference between the revenue of producers and importers and the expenditures of consumers. The reduction in revenue to the transport and distribution sector, standard minus reference case, represents a cost savings, because regulation assures the owners an adequate return on their investments.

### ***3.1.7 Natural Gas Import/Export***

Focusing on the U.S. economy, we assume that expenditures for imports are a “loss” to the U.S. economy, or at least a transfer from the United States to another economy. Thus, a reduction in expenditures for imports can be considered an offset to transfers to consumers from other sectors of the economy. As importation requires investment by U.S. firms in transportation and terminal infrastructure, this is an oversimplification. However, further analysis is beyond the scope of this study.

### ***3.1.8 Producers***

The reduction in demand for natural gas associated with the introduction of an efficiency standard, like any reduction in demand for natural gas, will likely result in a decrease in the total profits earned by gas producers. Reduced production, even at a constant profit margin, will naturally result in lower total profits.

When the introduction of a standard is fully anticipated, the associated reduction in demand will only result in a reduction in opportunities for profitable investment in natural gas production. That reduction is not a loss to investors and simply induces an appropriate shift in capital to other sectors or other profitable opportunities in the same sector (Kuuskraa, 2008). Only when the reduction in demand is unanticipated and investments are sunk, that is, they cannot be deployed to other activities, can a real loss of profit occur.<sup>24</sup>

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<sup>24</sup> Many of the capital assets required for natural gas production (the well holes, for example) cannot be redirected to other activities once the capital expenditures have been made. That is, the expenditures are sunk.

As noted previously, it seems unlikely that the effects of a standard could be unanticipated to the extent that producers' investment decisions are adversely affected. However, by assuming that the effect of the standard is a complete surprise to producers and investors, we establish an upper bound on the loss of producer profit, leaving it to others to determine whether the change in profit should be considered a real loss or simply represents a shift in capital to other uses.

### **3.1.8.1 Effect on pre-standard investments**

As described above, the production of natural gas requires the expenditure of substantial sunk capital investment before production can begin, as well as ongoing expenditures associated with actual production. If a particular investment is undertaken on the basis of a forecast that does not anticipate the reduction in demand and price due to a standard, the actual revenue may be lower than that anticipated when the profitability of the investment was evaluated. That is, had the effect of the standard been anticipated, the investors may not have invested in the particular project or may have modified their capital expenditures to maintain its profitability in the face of the reduced demand. The sunk nature of the investments precludes the investors from reducing their loss of profit by shifting assets.

Had the standard been foreseen, investors would have directed their capital to other projects with nearly equal returns that would not be affected by the standard. As a result, capital projects that would have been more profitable may have been foregone as a result of the standard, and economy-wide productivity of capital would be reduced. That portion of the transfer represented by the reduction in total profit is a loss to the economy resulting from the unanticipated introduction of a standard.<sup>25</sup>

The reduction in producers' profit from sunk investments made without foreknowledge of the standard is a cost of the standard and can be considered a transfer from the investors in gas production to those who benefit from the standard. If it is assumed that the effect of the standard is unanticipated, that all investments are sunk and that operating

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<sup>25</sup> For example, an investor may have had two projects available for investment, development of a natural gas well and the other in an unrelated industry. Both have an expected return of 10 percent. The investor chooses the natural gas project. However, the introduction of a standard reduces demand for natural gas, and the actual return is only 8 percent, indicating that the available capital should have been invested in the alternate project. The lost return on the alternate investment that was not made is a loss not only to the investor but to the economy as a whole.

costs are fixed, this transfer can be estimated as the difference in revenue generated by pre-standard investments in the reference and standard case.

### **3.1.8.2 Effect on post-standard investments**

Once the specification and introduction date of the standard is known, its effects on demand and price can be included in investment decisions. Investments made subsequent to the introduction of the standard cannot, therefore, be adversely affected by its introduction. The revenue generated in the post-standard period may be less in the standard case than in the reference case, but that simply reflects a shift of capital, not a loss of profit. Given efficient capital markets, investors can simply shift their investment to other projects, perhaps in other sectors, which are only marginally less profitable. It does not represent a loss to the economy, because the available capital was shifted to other available investments with little loss of return. As a result, any reduction in producer revenue from post-standard investments is not counted as a loss to investors.

## **3.2 Implementation**

We used the results from the reference and standards case runs from the NEMS-BT (2010 version) provided by LBNL. The alternate, or “standards” case, is constructed by imposing a series of decrements to gas usage on the reference run, beginning in 2015, the year the water heater standard is slated to be implemented. This study used energy demand changes that were calculated exogenously by the Energy Efficiency Standards Group at LBNL in its analysis of Federal appliance standards for residential water heaters.<sup>26</sup> In addition to natural gas savings, the standard case used here applies an increase in residential electricity demand resulting from projected switching from gas furnaces to electric heating equipment.

The method described above requires identification of pre- and post-standard investments and the profit associated with each set of assets. Fortunately, the method used by NEMS to construct its supply curve for natural gas facilitates that identification. NEMS constructs its long-term supply curve by evaluating, in light of its current price and demand forecasts, the profitability of available reserve-creating projects.<sup>27</sup> Profitable projects are undertaken, adding to the stock of reserves. NEMS tracks the creation of

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<sup>26</sup> For a detailed description of the analysis, see United States Department of Energy (DOE), 2009. The case used here is one that analyzes the effect of a standard on residential gas water heaters.

<sup>27</sup> Reserves in this context are assets from which production will begin in the next year.



“reserves” over time, allowing the estimation of production resulting from investments made prior to and subsequent to the introduction of a standard.<sup>28</sup> The reduction in revenue associated with reserves created prior to the introduction of the standard, relative to the case in which there is no standard, provides an estimate of the reduction in return from investments made prior to the introduction of the standard. Since profit is simply revenue minus cost, if cost does not change but revenue declines, the reduction in profit is simply the reduction in revenue.<sup>29</sup> To the extent that investments are not sunk—that is, they can be moved to other more profitable uses—or operating costs can be reduced, producers will be able to mitigate the effect of the standard on profitability. Assuming that all investments are sunk and costs are fixed provides the most conservative, or the largest, estimate of lost profit.

The standard only adversely affects investments made prior to the announcement of the standard, which in this case is assumed to take place in 2010. The reduction in producer profit is calculated as the reduction in revenue (standard case minus reference case) associated with reserves created prior to the announcement of the standard.<sup>30</sup> Because we are estimating only the differential effect of the standard, there is no need to consider whether profits from investments made prior to the standard are higher or lower than anticipated at the time the investment decision was made. This method isolates the effect of the standard, assuming all other external factors remain the same.<sup>31</sup>

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<sup>28</sup> NEMS does not track production from each reserve cohort but, with the simplifying assumption that all reserves produce at the average production/reserve ratio, production can be assigned to each reserve cohort.

<sup>29</sup> We assume that all reserves are drawn down at the average production-reserve ratio. In actuality, the P/R ratio is probably much higher in the early portion of a well’s life. In that case our assumption overstates the production from these reserves that is exposed to the lower demand and price resulting from the standard.

<sup>30</sup> We make the conservative assumption that production from pre-standard reserves is the same in the reference and standards case. That is, producers do not adjust their extraction rate from pre-standard reserves to accommodate the decrease in demand resulting from the implementation of the standard.

<sup>31</sup> In this specification the decline in natural gas prices resulting from the decrement in demand affects only investments subsequent to the implementation of the standard. Investors could actually incorporate an estimate of the future price decline on profitability of investments as soon as they become aware of scheduled implementation (i.e. 5 years prior to implementation). This inconsistency between the model specification and reality will result in some overestimate of reserve creation during the period between announcement and implementation of the standard.

## 4 RESULTS

(all values in Billions of Dollars)

	NPV 2010	Sum
Discount Rate	7.0%	
<b>Consumers (negative indicates benefit, i.e. reduced expenditure)</b>		
Residential		
Gas	-\$12.83	-\$30.67
Electricity	\$0.57	\$1.20
Commercial		
Gas	-\$1.27	-\$3.04
Electricity	-\$1.76	-\$4.57
Industrial		
Gas	-\$2.23	-\$5.28
Electricity	-\$0.83	-\$2.10
Transportation		
Gas	-\$0.25	-\$0.69
Electricity	-\$0.01	-\$0.03
Electric Power		
Gas	-\$1.75	-\$4.41
<b>Total benefit to consumers (negative indicates lower expenditure)</b>		
Natural Gas	-\$18.08	-\$43.40
Electricity	-\$2.02	-\$5.47
<b>Total Benefit (\$ Billions)</b>	<b>-\$20.10</b>	<b>-\$48.87</b>
<b>Transfers from other sectors (negative indicates transfer to consumers)</b>		
<b>Government:</b> share of royalties and taxes (reduced taxes and royalties)	-\$2.89	-\$7.07
<b>Private land/rights owners:</b> (reduced royalties)	-\$1.14	-\$2.73
<b>Producers:</b> (negative indicates reduced revenue)		
Lower 48 NG revenue (negative indicates reduced revenue)		
Pre-Standard (up to 2009) Reserves	-\$0.97	-\$1.90
Post-Standard (2010 & up) Reserves (\$ Billions)	-\$3.84	-\$9.91
Total Reduction in Revenue from Production of NG	-\$8.84	-\$21.61
Total Transfers (including reduced revenue on pre-2010 reserves)	-\$5.00	-\$11.71
<b>Total Transfers (excluding reduced revenue on pre-2010 reserves)</b>	<b>-\$4.03</b>	<b>-\$9.81</b>
<b>Net Benefits (Total Less Transfers) (\$ Billions)</b>	<b>-\$16.07</b>	<b>-\$39.06</b>

The introduction of the standard results is an undiscounted benefit to residential consumers of \$29.5 billion<sup>32</sup> over the years from 2015 to 2035 and a total undiscounted benefit to consumers of natural gas of \$43.4 billion over the same period. In addition, electricity consumers enjoy a benefit of \$5.4 billion. Benefits to all consumers of natural gas and electricity total \$48.9 billion.

<sup>32</sup> Note that this is gross since it does not include any increased expenditure for standard compliant appliances.

These benefits to consumers include a total of \$9.8 billion (about 25 percent of the total benefit) in transfers from landowners and taxpayers. An additional reduction in revenue of \$1.9 billion may represent lost profit to producers. The net benefit is therefore \$39.1 billion, or \$37.2 billion if the potential loss to producers is included.

## **5 CONCLUSION**

The introduction of an appliance efficiency standard that reduces the demand for natural gas has a direct benefit to consumers who purchase the covered appliances. It indirectly benefits other consumers of natural gas through the reduction in natural gas prices associated with reduced demand. Approximately 25 percent of this benefit is the result of transfers from other economic sectors, including taxpayers and owners of natural gas reservoirs. The true benefit of the standard should be stated net of these transfers. Profitable investment opportunities in the natural gas production sector are reduced by the introduction of a standard. However, the long lead-time associated with the introduction of a standard makes it unlikely that the profitability of investments that are actually made will be adversely affected by the reduced demand associated with the standard. As long as capital markets are reasonably efficient, the reduction in investment opportunities in the gas production sector will simply lead to a shift of capital from that sector to other sectors of the economy.

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