increased operating experience, result in a cost structure that approaches the low end of the estimated range, then the total life cycle cost of a 10 megawatt PAFC system would be around 60 mills per kilowatthour.Fuel cell research and development activities both from the resource perspective, and from the new products / customer service perspective, will continue to be monitored and evaluated as part of the evolving planning process.

Electric Transportation: Advances in electric transportation technologies are being monitored in anticipation of the development of a competitively-priced, dependable, and acceptable alternative to oil-based transportation. Unlike the other new technologies discussed so far which could potentially add to the resource portfolio, advancements in electrified transportation represents a potentially large source of new load.

Developments in the research and development of electrical transportation vehicles will continue to be monitored and evaluated as part of the evolving planning process. The widespread diffusion of electric vehicles would have a significant impact on the amount of load, and upon the mix of resources utilized to serve that load.

The Evaluation of External Costs

Introduction: The Oregon Public Utility Commission, as part of its least cost planning order, instructed the Company to evaluate to the fullest extent practical and quantifiable, the costs and benefits external to any resource transaction. External costs are defined as those that may be imposed on society at large, and not borne directly by the Company or its customers. Although the Commission provided no specific details as to how such consideration is to be put into practice, from a power planning perspective, the issue appears to be whether or not the relative priority would change between new resources included within the supply and demand-side portfolios.

The basic analytical approach that was taken by the Company to account for external costs was to estimate the range of costs associated with controlling and/or reducing major emissions, such as SO2, NOX, and CO2, at the powerplant. The Company received comments during the technical advisory group process, and through written comments following the issuance of the draft RAMPP report, that indicated a desire on the part of many reviewers for a more complete determination of the costs associated with the effects of these, and other potential environmental hazards and risks.

While a more complete assessment of environmental risks and hazards, and their relative contribution to the total cost of new resources would add to the planning knowledge base, it would not have an immediate effect on short-term resource decisions as discussed in Volume 1. In addition, to be effective, this assessment must go beyond the environmental effects that are uniquely associated with electricity, and incorporate the interrelationships among other energy sources and uses.

For example, in order to reduce world carbon dioxide levels utilities might convert existing coal-fired facilities to natural gas. The resulting increase in natural gas demand could have several important ramifications, such as: increased natural gas exploration and transportation in environmentally sensitive areas, increased requirements for natural gas end end use efficiency programs, and energy price increases that could induce some customers to burn more wood or oil for space heat.

Another example would be where global warming concerns lead to the widespread diffusion of electric vehicles. A situation can be envisioned where electric utilities might be required to operate natural gas-fired generation in order to facilitate the carbon dioxide reduction of the personal transportation industry. However, it is possible that the transportation industry could provide offsets to the electric and natural gas industries in order to facilitate a process that would result in a net reduction in carbon dioxide emissions. A variation of this example is where the utility utilizes the cash value of these offsets to fund increased end use efficiency programs and/or renewable resource development in order to make sufficient capacity available to meet the needs of the transportation industry.

These two examples, which indicate the interrelationship among all energy sources and uses, point to the necessity of evaluating environmental costs on a total energy basis.

The Company will work to improve its method of quantifying the costs associated with various environmental effects, and incorporate these costs into its new resource selection process over the next two years. The Company is confident that the ultimate results of this "effects-based" environmental cost methodology will not appreciably alter the long-term resource planning results contained in this report. The Company bases this confidence on the fact that in nearly all forecast cases and scenarios the majority of identified, cost effective, end-use efficiency-based options are employed prior to the exercising of thermal-based resource options. In addition, the timing and sequence of new resource options generally follows a graduated, low-to-high, environmental effects scale. Typically, energy and system efficiency programs are the first options selected, followed by hydro firming, cogeneration, purchases, combustion turbines, renewable resources, and coal facilities. It is possible that under some demand forecast assumptions the timing and/or sequence of acquisition of a resource such as a gas-fired combustion turbine may be altered relative to a coal-based power purchase. However, if the demand assumption is high enough to require the acquisition of both resources, and if the environmental effects "adder" is not large enough to alter the relative economics of the next highest cost efficiency program or renewable resource, then both the combustion turbine and the power purchase will be acquired during the forecast period.

Method: As part of the RAMPP process, an evaluation of the effect that certain external costs may have on the determination of the cost-effectiveness of various resource options was undertaken. Resource costs were evaluated that could be internalized at some time in the future, as well as some external costs whose potential internalization is more speculative. This process consisted of the following steps: 1) an identification and appraisal of externalities, 2) a decision phase where, for each major type of external cost, the value of proceeding with further evaluation was balanced against the ability of that factor to influence the relative priority of a given resource decision in relation of other supply and demand-side options and 3) the incorporation of various analyses and speculations into the resource choice process.

Step 1: Appraisal of Externalities An appraisal of externalities that could have an impact upon the cost-effectiveness of a resource option was undertaken. The resulting list of possible externalities was long and diverse. Table 35 presents a partial list of potential externalities that could affect a particular resource decision. This list is not an exhaustive list of possible externalities A review of this table reveals list of possible externalities that could impact any

Table 35

POSSIBLE EXTERNALITIES

Acid Deposition Impacts	Ground Water Impact	Recreation Impact
Aesthetic Impact	Heat Pollution Effects	Resource Depletion
Agricultural Impact	Magnetic Field Effects	Runoff from Mines
Carbon Dioxide Emissions	Noise Effects	Sulfur Dioxide
Crop Yield Effects	Nitrous Oxides	Surface Water Impacts
Displacement of People	Ozone Effects	Technology Advancement
Displacement of Wildlife	Particulate Emission	Toxic Emissions
Effect of Property Values	PCB's	Waste Water Discharge
Effects on Visibility	Proximity to Population	Water Flow/Distribution Effect
Endangered Species Impact	Public Acceptance	Wetlands Impact
Fish Impact	Public Lands Encroachment	Radon

one of a number of resource options. Notably missing from this list are economic development and job creation, or job loss effects that were included, in compliance with the Oregon Commission's least cost planning order.

A number of the possible externalities listed on Table 35 can be considered as already internalized within the resource, and program, cost estimates. Externalities within this group include: fish and wildlife, ground and surface water, PCB's, mine runoff, radon, toxic emissions, waste water discharge, and wetlands impact.

Another group of possible externalities proved to be difficult to evaluate in terms of their relative impact upon the various resource options under evaluation. Externalities within this group include: aesthetic impact, agricultural impact, effect on property values, effects of visibility, magnetic field effects, public lands encroachment, resource depletion, and technology advancement.

A further group of potential externalities emerged as having the capability to influence the cost-effectiveness of a resource option over the plans 20-year horizon, and therefore influence the choice decision. Not surprisingly, these potential externalities are those currently receiving a significant amount of media, research, and political attention. Externalities within this group include: carbon dioxide emissions, nitrous oxide emissions, and sulfur dioxide emissions.

Step 2: Decision Phase A literature review of the estimated range of effects associated with each major externality was performed. A judgmental weight was then applied to each resource option in proportion to this range. A further decision was made to focus on the direct impact of a possible externality, and not to attempt to model a speculative chain of events that could be associated with each externality. For instance, while a range of costs associated with increased emissions were assumed for the purchase of coal-fired electricity from the desert southwest, the effects related to possible future resource or program decisions made by the selling utility were not incorporated - the external effects associated with large scale production of fiberglass (building insulation) and gallium arsenide (photovoltaic cells) were also not specifically evaluated.

It was determined that little useful power planning information would be gained by evaluating the relative cost-effectiveness of one resource option versus another through the quantification of minor externalities which affect all options to varying degrees. This proposition was tested by applying modest (1 to 3 mills per kilowatthour) additions to different program and option costs. This test resulted in no appreciable change in the resource choice and timing decision, under each load growth case, when compared to a situation where the external cost additions were not included. The only tangible effect was that each resource become slightly more expensive as these additional costs were applied.

As a result it was decided to concentrate analytical efforts in the area of quantifying the potential external costs of the externalities that could have the capability to greatly influence the cost-effectiveness of one resource option versus another, and therefore influence the resource choice decision. The potential external costs that the Company decided to evaluate more fully were those attributable to: carbon dioxide emissions, nitrous oxide emissions, and sulfur dioxide emissions.

Step 3: Incorporation into the Resource Choice Process Evaluations were made of the costs associated with additional emission control and mitigation technologies and techniques at existing, facilities. In addition, the costs associated with these technologies and techniques were included as part of the evaluation of those new resources which emitted these gases. Included in the category of new resources were potential sources of purchased power. Each source of purchased power was evaluated in order to arrive at a rough approximation of the proportion of each primary fuel-type used to generate that purchased power. The emission control standards included within President Bush's proposed Clean Air Act of 1989 were used as benchmarks in determining the range of costs associated with any control or mitigation process that might be required during the next twenty years.
The results of this portion of the external costs process helped verify the effectiveness of the portfolio approach to resource planning in terms of its ability to acquire new resources at least cost. The external costs process helped lead toward the selection of low-cost energy efficiency, and system efficiency, programs as the least cost resource option exercised in its initial two-year action plan.

In addition to the above analysis, a speculative "global warming" scenario was developed that encompassed a broader array of options that might consider exercising that would alter the costs and types of any future resources that might be required, and alter the fuel choice and operation of some existing resources, in order to arrive at a substantial reduction in overall carbon dioxide emissions. (This scenario is discussed more fully in the section dealing with Alternate Futures.) The purpose of this scenario, in addition to incorporating the risks associated with this situation within the two-year action plan, was to test the flexibility in dealing with a hypothetical situation where global warming is internationally recognized as a serious environmental problem, and that significant steps are taken worldwide to reduce the release of man-made carbon dioxide into the atmosphere. The operating goal of this scenario is that the Company acts to reduce its total carbon dioxide emissions by 20 percent by the year 2005.

The approach that was taken by the Company in the global warming scenario was very comprehensive. In exercising the options required to reduce its total carbon dioxide emissions by 20 percent the Company modeled significant alterations its existing resource base. In one variation, a significant proportion of existing coal-fired generation was repowered to natural gas. In the other variation a significant amount of existing coal-fired generation was removed from service and replaced with renewable resources whose costs had declined to levels associated with the most optimistic future estimates currently available.

The results of this portion of the external costs process helped verify the effectiveness of the portfolio approach to resource planning as well as the Company's ability to effectively meet the energy service needs of customers while at the same time reducing its carbon dioxide emissions. Unfortunately, the response to this situation, either with repowering coal facilities to natural; gas, engaging in a significant tree planting program, or relying upon large amounts of as-yet undeveloped low-cost renewable resources, carries a heavy price tag. In each run of the "global warming" scenario utility costs rise significantly in the latter years of the forecast. The resulting increase in the price of all energy forms, and the possibility that as-yet unknown or untested energy efficiency devices will be developed, leads to the conclusion that the demand for electric energy in this hypothetical environment will tend to be in the low, to medium-low, forecast range.

Table 36 displays the estimated range of costs associated with some emission control technologies for sulfur dioxide, nitrous oxide, and carbon dioxide. The costs associated with

Table 36

Estimated Range of Costs Associated With Emissions Control

Technique	Total Capital Cost ($ Per KW)	O&M Cost (Mills per KWH)	O&M Cost ($ Per Ton Removed)
SO2			
Conventional Limestone FGD	$100 to $120	2 to 3	$500 to $700
NOX			
Low NOX Burner	$2.00	-	-
Urea Injection	$2.00	6 to 8	$1800 to $2,000
CO2			
CO2 Scrubber inc. FGD (Hypothetical) (1)	$300 to $400 *plus* $100 to $200 for Disposal	10 to 12	$10 to $12
Gas Co-Firing (2)	$20	6 to 12	$5 to $10
Tree Planting (3)	$75 to $150	1 to 7	1 to 6

Notes:

1. Technology effectiveness unknown for large-scale power plant applications. In addition, prior FGD installation is required. Disposal method assumes deep ocean storage.
2. O&M costs assume "Low-Case" fossil fuel prices. No allowance made for fuel shortage.
3. 750,000 acres of trees are required to capture the carbon output of a 300 MWa coal facility

Further Reading:

1. Michael Shepard, "The Politics of Climate", EPRI Journal, Volume 13, Number 4: June 1988.

2. John Douglas, "Quickening the Pace in Clean Coal Technology", EPRI Journal, Volume 14/ Number 1: January/February 1989.

3. Mark Casper, "The Greenhouse Effect, A Utility Perspective", Presentation at EEI Conference: Electric Utilities in the Year 2000, November 18, 1988.

4. John Kinsman & Gregg Marland, "Contribution of Deforestation to Atmospheric CO2 and Reforestation as an Option to Control CO2", Presentation to Air & Waste Management Association, June 25-30, 1989.

emissions control was utilized as a surrogate for the external costs associated with the uncertain effects of these emissions. This range of costs highlights the difficulty associated with assigning, with any level of assurance, a range of costs to any particular emission control technology. These technologies display a tremendous variability both in terms of total capital cost, and in estimated O&M costs. With regard to carbon dioxide, there are additional uncertainties associated with each of the three control techniques listed. The hypothetical scrubber technology is not only untested in terms of its applicability for large-scale stack gas collection, but has an additional difficulty associated with CO2 disposal. The economics of co-firing with natural gas depends to a large extent upon the fuel's price and availability. The economics of large-scale, plantation style, tree planting techniques are dependent upon the price of available land, the cost of ongoing maintenance, and the willingness of society, particularly third-world societies, to allow the plantation to stand undisturbed for several generations (80 to 100 years).