Energy and Irrigation in Washington

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The magnitude of energy costs imposed on the general public by irrigation development in Washington is very large. These costs come about through two separate phenomena. As water is withdrawn from the Snake and Columbia Rivers for irrigation, use of this water for creating hydropower is lost. Also, pumping of water for irrigation requires significant quantities of electricity which is currently sold to irrigators at very low average costs. However, both the lost and used energy must be replaced or added to the supply at the opportunity cost of current thermal power generation. These phenomena result in a cost of about $150 per acre per year that is paid by the general public through increased utility rates. This article describes the magnitude of such costs in terms of large and small family farms, and in terms of employment created by irrigation development.

The energy costs of new irrigation are large and the magnitude and distribution of these costs should be investigated and considered in evaluating the feasibility and desirability of future irrigation projects in the West. This article describes possible impacts on hydroelectric energy production and subsequent energy costs imposed on all people within the region resulting from diverting water to develop large irrigation projects in eastern Washington.[1]

Irrigation diversions in the Pacific Northwest impact on energy supplies in two ways. They reduce the amount of hydroelectric energy produced in the Columbia River system while consuming large amounts of energy for lifting the water above the river and distributing it to farms for irrigation. Increased irrigation results simultaneously in less energy production and higher energy demand. Society is ultimately faced with the prospect of much higher energy costs and potential shortages in the future. Thus, the energy cost of future irrigation diversions is a relevant factor for society to consider in decisions about the allocation of water resources. Furthermore, these higher energy costs will be imposed generally on all energy consumers in the affected region rather than being borne fully by the users of irrigation water.

Consumption of electrical energy in the northwest states (Idaho, Oregon, and Washington), for example, increased at an average annual growth rate of 7.5 percent during the 1960-70 decade and is projected to continue increasing at 5 percent or more annually to 1990, excluding power requirements of irrigation development [BPA, July 13, 1972]. Aside from potential irrigation development, projected expansion in average firm energy requirements in the Pacific Northwest from 1974 to 1985 will require adding production capability equivalent to the energy output of a 1200-megawatt, nuclear power plant each year [PNWRBC, May, 1974, p. 84]. Thus, any irrigation diversion that reduces hydropower potential and increases demand for electricity will eventually impose a cost on all electrical users through increased utility rates. Only if reductions in demand for electricity outside agriculture equal those imposed by irrigation development would the need to add to regional power production capacity, as assumed in this analysis, be eliminated.

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[1]A portion of this paper is based on an earlier study by Schuy.

It is important to note at the outset that from 1980 onward there will be sufficient generation capacity in the hydropower system to utilize all normal stream flows throughout the year. Thus, any diversions for irrigation will detract from the potential to create hydropower.

Assumptions and Methods

This analysis first considers major potential diversions for irrigation from behind Grand Coulee Dam on the Columbia River.[2] The Bonneville Power Administration (BPA) staff used a computer simulation model to estimate the impact of these diversions on the energy generating capability of the Columbia River hydroelectric system under 1984-85 conditions. From these simulation estimates, the cost of generating additional energy to replace hydroelectric losses and meet the energy load used for pumping to divert and distribute irrigation water was calculated.

Initially this study assumed a diversion of three million acre feet annually. With a delivery and farm distribution system having an overall efficiency of 70 percent, this amount of water is approximately sufficient to provide a full irrigation supply to 860,000 acres of land in the Lincoln-Adams County area of central Washington lying east of and adjacent to the present Columbia Basin Project, assuming a diversion and delivery of 3.5 acre feet of water per acre. Current Bureau of Reclamation plans for expanding the Columbia Basin Project by about 500,000 acres are to divert 4.3 acre feet of water per acre with a farm delivery of about 3.5 acre feet per acre, an even larger diversion per acre than that used in this analysis.

Two alternative patterns of diversion from the Columbia River are evaluated. Plan A considered the use of an offstream storage site with a usable capacity of 1.1 million acre feet, allowing water to be diverted from the Columbia River under continuous pumping for an eight-month period from March through October. Monthly diversions during this period would be a constant 375,000 acre feet.

For Plan B, the monthly diversions were based upon directly satisfying the estimated crop irrigation requirements for the month, without an offstream storage capability. The pattern of crop irrigation demand was based on typical grain and field crop production for the area. The monthly diversion patterns of the two plans are shown in Table 1.

Reduction of Hydroelectric Energy Due to Diversion

The simulation model took into consideration projected load pattern, critical period stream flows, total available storage, and the operating characteristics or constraints of all generating plants in the system. Firm energy is energy which the system can always produce on a sustained basis, even under critical period hydrologic conditions. The latter term refers, in general, to the lowest recorded stream flows, although technically the critical period is determined by a combination of historical low stream flow conditions, available storage, and projected power load.

Water diverted from the river for irrigation is lost for generation of electrical energy at downstream power plants, except to the extent that any waste or seepage waters might eventually return to the river. This analysis assumes that return flows are negligible because of the high costs of obtaining irrigation water and the ample opportunities for capturing and reusing any waste or seepage water on other irrigable lands.

The time period selected for this study to estimate energy losses was beyond 1980, although costs are stated in terms of 1980 dollars. The hydroelectric generating system essentially will be completed by 1978 with only

[2]Schuy, in cooperation with the Bonneville Power Administration's Branch of Power Resources conducted the analysis of energy requirements and costs, with supplemental information from the Thermal Nuclear Analysis Staff. Dr. Gene Thompson, Department of Agricultural Engineering, WSU, prepared the hypothetical diversion problem used in the study.

TABLE 1. Monthly diversion pattern and annual power loss for three million acre feet annual irrigation diversion from Franklin D. Roosevelt Lake, Columbia River

	Unit	Plan A[a]	Plan B[b]
March	1000 AF	375	–
April	1000 AF	375	90
May	1000 AF	375	450
June	1000 AF	375	600
July	1000 AF	375	780
August	1000 AF	375	750
September	1000 AF	375	330
October	1000 AF	375	–
Total	1000 AF	3,000	3,000
Annual loss			
Capacity	MW	367	290
Energy	MWH	2,338,920	2,540,400

[a]Continuous pumping for eight months. Requires 1,100,000 acre feet offstream storage.
[b]Pump on irrigation demand.

minor installations thereafter to increase peaking capacity. This peaking capacity will be integrated with the addition of coal or nuclear plants for base load generation. The 1984-85 conditions are representative of the next 20 years of operation for the electrical energy system.

Given the amount and pattern of diversions plus the change in system energy loads caused by additional irrigation pumping requirements, the computer model simulates the operation of the entire generating system in order to provide maximum firm energy output during the projected 1984-85 conditions. In other words, given a diversion of three million acre feet, the computer model simulates operation of the hydropower plants in the system to minimize the loss of firm energy. The amount of energy loss due to irrigation diversion is also shown in Table 1.

To place these estimates in perspective, the amount of loss resulting from Plan B is about one-third of the average annual production from a 1200-megawatt, nuclear power plant operating at an average plant factor of 75 percent. Another measure of the energy loss from this diversion is that quantity that would supply electricity to about 170 thousand homes in the Northwest based upon an average consumption of 13,831 kwh per residential consumer in 1970 [BPA, April, 1973].

Economic Value

One procedure for estimating the cost of replacing the energy lost from irrigation diversions is to multiply the energy loss in kilowatt hours by BPA's current wholesale power rate for firm energy.[3] However, this procedure would provide a very misleading measure of the societal opportunity cost of electrical energy because this rate is less than the cost of required additions to the generating system. The BPA rate structure is an average cost pricing method designed to recover actual costs of all plants in the Federal Columbia River Power System. Most of the hydropower plants represent a very inexpensive source of electric energy compared to the costs of any future additions to the Pacific Northwest Power Pool through thermal generation plants. About one-half of the existing dams and power plants are amortized at 2.5 percent interest, with the balance ranging from 3 to 3.342 percent [USDI, 1973, p. 60-61]. The current BPA wholesale rate for electricity is about 3.0 mills per kwh.

[3]In 1974 the average cost per kwh paid to Bonneville Power Administration by its preferred utility customers was 2.89 mills, while the average paid by all residential customers was 9.98 mills per kwh [Washington Public Power Supply System, 1975]. Neither of these figures reflect retail utility rates because they do not include electricity distribution costs. The 1977 BPA cost to preferred utility customers was about 3.5 mills per kwh.

Nuclear plants now being constructed by Washington Public Power Supply System are financed with capital costs up to 7.75 percent interest. Plants financed and constructed by private firms are paying even higher interest rates for capital. The Northwest utilities intend that part of the projected firm energy deficit prior to 1980 will be met by planned or proposed coal-fired, thermal plants, located primarily in Wyoming. Much of the deficit after 1980 will be provided by additional nuclear plants. However, a recent study conducted by the Washington Public Power Supply System (1977) shows that costs of electricity from new coal or nuclear generation facilities are about equal.

Even if all the planned or proposed thermal plants are completed on schedule (an improbable eventuality), there would still be firm energy deficits in the region if critical period hydrologic conditions occur prior to 1985. Therefore, it appears likely that any future reduction in hydropower production through irrigation development would have to be provided entirely by building additional thermal generating capacity. These factors imply that the opportunity cost of diverting water for irrigation is represented by the cost of generating replacement power from efficiently scaled thermal power plants.[4]

Cost of the Thermal Nuclear Alternative

Capital costs of nuclear power plants have been escalating at an average annual rate of 26 percent since 1970 [Olds, 1974]. Average capital cost per kilowatt of capacity was $199 in 1965, and $588 in 1974. A 1240-megawatt plant now being constructed and under ownership of the Washington Public Power Supply System, with planned power production in 1982, will have a capital cost of $1003 per kw of capacity or a total of $1244 million. It is expected that projections made for 1984 would be above the highest estimate shown here.

The recent Washington Public Power Supply System (1977) study shows that nuclear power in 1980 dollar terms would cost approximately 30 mills per kwh. These costs are based on an assumed 65 percent plant factor, 7 percent interest rate, and an 8.3 percent fixed charge rate (including amortization, capital replacements, and insurance). The remainder of this analysis will use this value to represent the opportunity cost of replacement energy for irrigation development.

Annual Cost of Replacing Energy Losses

The annual costs of replacing hydroelectric energy losses resulting from the proposed diversions are shown in Table 2. The total annual cost associated with Plan B is $76.2 million or an average of 25.41 per acre foot diverted. Corresponding costs for Plan A are $70.2 million and $23.40 per acre foot Both [Hastay (1970)] and [Dutton and Millham (1972)] estimated energy losses from diversion above Grand Coulee Dam to be 27 percent greater than for Plan B. However, their studies are not directly comparable because of variations in assumptions and cost estimates.

Energy Requirements for Irrigation Pumping

Additional energy requirements for lifting and distributing water are greater than the losses resulting from diversion. For example, direct diversion of 3 million acre feet (Plan B) results in a system energy loss of 2.5 billion kwh, plus an additional energy load of 4.5 billion kwh for the pump lift and .6 billion kwh for distribution to farms under pressure. The total system loss plus energy load of this plan is 7.6 billion kwh, which is only slightly less than the annual firm energy production from a 1200-megawatt nuclear power plant. The diversion pumping load assumes a lift of 1,240 feet from Franklin D. Roosevelt Lake

[4]In reality, other instream uses of water should be valued and added to the instream energy value of water. These uses include navigation, fish passage, recreation, and pollution abatement.

TABLE 2. Estimated energy losses, requirements and costs of replacement under plans A and B.

	Unit	Plan A	Plan B
Annual Diversion	1000 AF	3000	3000
System Energy Loss	Kwh/AF	780	847
Pumping Energy Used	Kwh/AF	1700	1700
Total Energy	Kwh/AF	2480	2547
Annual Cost[a]			
Energy loss	$/AF	23.40	25.41
Energy used	$/AF	51.00	51.00
Total	$/AF	74.40	76.41

[a]Energy replacement costs estimated at 30 mills per kwh.

to the lands to be irrigated. It was also assumed that water would be delivered to the farm through a closed pipe distribution system at 60 pounds pressure per square inch, with 20 percent friction loss. Water would be applied to crops through sprinkler irrigation systems.

The total cost of the energy requirements, lost hydropower plus energy used, of each diversion was calculated in two ways. In the first method, it was assumed that the energy is provided at a cost equal to the projected average cost of firm energy from a 1200-megawatt nuclear power plant at 30 mills per kwh. The energy impacts and costs per acre foot of water diverted under this assumption are shown in Table 2. Total energy replacement costs are close to $75 per acre foot diverted under each plan. The total annual energy costs of Plans A and B are virtually the same under this method of analysis ($223.2 million and $229.2 million, respectively). Assuming that 3.5 acre feet of water are required for each acre, the total annual cost for energy would approach $260 per acre. It is important to note that this cost is in addition to other construction costs usually considered in calculating project feasibility. Payment for energy by agriculture for a project adjacent to the one under study here is planned by the U.S. Bureau of Reclamation to be 0.5 mill per kwh for energy used and zero for energy lost. Thus the entire opportunity cost of the energy becomes an external cost to be imposed on the public through higher utility rates.

The second method of calculation estimated the cost of additional generating resources needed to meet the peak monthly and annual energy requirements of the different plans. Plan B had substantially higher costs than Plan A because of the higher peak monthly energy use under Plan B (pumping on irrigation demand). Three alternative schemes for supplying required energy were considered. The results of these estimates are shown in Table 3. These cost data are based on capital and operating costs of a particular generating facility while data in Table 2 are based on a flat rate of 30 mills per kwh.

Both the monthly and annual energy requirements of Plan A (offstream storage) could be satisfied by a 1200-megawatt nuclear plant, Table 3. A small amount of surplus energy would be left over which is assumed to be sold at 5 mills per kwh. Thus the costs of Plan A are slightly lower under the second method. However, construction costs for this type project would include a very large regulating reservoir which would be unnecessary under the second method.

However, in order to satisfy the high peak monthly use of pumping on irrigation demand under Plan B, a 2210 MW nuclear plant would have to be built, or some combination of a smaller nuclear plant plus a pumped-storage or coal-fired peaking plant as shown in Table 3. The strictly nuclear alternative results in production of a substantial amount of surplus energy. This scheme provides a net annual cost for irrigation diversions equal to $312.4 million, $104.14 per acre foot diverted, or about $364 per acre irrigated.

If surplus energy is valued at 5 mills per kwh, then the least cost method of serving Plan B is a combination of a 1200-megawatt nuclear plant and a 1010-megawatt pumped-storage plant. The cost of this method is an annual cost of $234.0 million, $78.00 per acre foot diverted, or $273 per acre irrigated.

The reason for showing the results of these two different methods of calculating the cost of energy impacts is due to some uncertainty about what value should be assigned to the surplus energy which would be generated under the BPA assumptions. The lower value may be justified on the basis that the surplus energy is available in a pattern fixed by the irrigation pumping load and replacement of system firm energy losses. Thus, whether it could be sold and at what price depends on (1) finding a buyer who could accept this particular pattern of availability, and (2) year-to-year variations in the cost of energy from other sources.

On the other hand, the surplus energy will be available during the winter period of peak and seasonal demand in the Northwest. Therefore, some may argue that there will be a ready market for the energy and it will have a value at least equal to the average annual cost of production. Resolution of these differing views could become important in a future project feasibility study. But, for this study, it is sufficient to know that the energy cost of a large-scale diversion under the assumptions stated is *at least* $65 per acre foot diverted, and possibly higher. Assuming that 3.5 acre feet of water will be used for each acre of land, the total cost of this energy could be as high as $230 per acre of land developed in the project considered for this analysis.

Who Pays the Cost?

Most energy costs of the future irrigation diversions will probably not be paid by irrigators if the present pricing policy for determining utility rates continues. The basic reason is that BPA wholesale power rates, and utility rates in general, are based upon average cost pricing. As we have seen, the cost of new generating resources is many times greater than the long-run average cost of all electrical energy generated which is the basis for setting power rates.

Assuming that the cost of power to USBR projects is 0.5 mills per kwh, irrigators under Plan B would pay $2.6 million for the 5.1

TABLE 3. Bonneville Power Administration estimated resources to serve electrical load

Plan	Investment ($000)	Annual Costs ($000)	Possible Sales of Surplus Energy[a] ($000)	Net Annual Cost After Energy Sales ($000)	Annual Cost/A Ft. Diverted ($)
A.					
1200 MW_e Nuclear Plant	1,518,000	194,000	1,228	192,772	64.26
B.					
1. 2210 MW_e Nuclear Plant	2,788,000	331,000	18,574	312,426	104.14
Or					
2. 1200 MW_e Nuclear Plant	1,518,000	196,000		196,000	
and 1010 MW Pumped-Storage	328,000	38,000		38,000	78.00
	1,846,000	234,000		234,000	
Or					
3. 1200 MW_e Nuclear Plant	1,518,000	187,000	5,645	181,355	
and 1010 MW Coal-Fired Peak		196,000		196,000	
		383,000		377,355	125.79

Source: Bonneville Power Adm., Branch of Power Resources, Aug. 23, 1974. Cost calculations were updated to a comparable 1980 level using data obtained from Information Services, Washington Public Power Supply System and a 5% escalation factor.

[a]Valued at 5 mills per kwh.

billion kwh consumed for irrigation pumping of 3 million acre feet. However, it would cost at least 30 mills per kwh or $228 million annually to generate the 7.6 billion kwh needed for irrigation pumping and replacing hydroelectric energy losses. The difference between generation costs and the amount paid by the irrigator — $225.4 million annually — would be paid by all Northwest consumers of electrical power in the form of utility rate increases. For the 860,000 acres potentially irrigated in this example there would be an annual subsidy by all consumers to the irrigation project of $262 per acre.

It is impossible to predict how future cost burdens of energy development might be shared among utility users. Given a specific proposal, the resulting distribution of the cost burden could be determined. But, it does seem unlikely that beneficiaries of water diversion will be required to accept the full burden of energy costs.

Other Diversions

Energy impacts associated with other development of irrigation as described above are also applicable to development in other areas of the state. These effects are shown by the data in Table 4. This table shows energy losses and consumption per acre foot of water diverted for irrigation project areas at specific dams along the Snake and Columbia Rivers. To irrigate lands of the Eureka Flats with water from behind Lower Monumental Dam would use 1163 kwh per acre foot of water diverted. Also, for each acre foot of water diverted there would be a loss of 463 kwh per acre foot of water used.

Table 4 also shows how societal costs would be affected by irrigation in these various areas. It is assumed that private agriculture developments are charged 3 mills per kwh of electricity used.[5] That is, the farm is assumed to pay 3 of the 30 mills per kwh that it will cost to replace the energy used to pump water.

It is shown that annual total energy costs for water could range from $48.78 per acre foot of water in the Eureka Flats to $13.14 in the Walla Walla project. Part of these costs, $3.49 and $0.45, respectively, would be paid by the farmers as indicated by the second from last column.

The last column of Table 4 shows the general energy subsidy provided to new irrigation development in Washington. Assuming that 3.5 acre feet of water is diverted for each acre, society will pay through ultimately higher rates for electricity as much as $140 annually for every additional acre irrigated in the Columbia Basin Project or $155 per acre for the East High Project.

[5]An additional 9 mills would be paid to cover distribution costs.

TABLE 4. Energy lost and used per acre foot of water used for irrigation and annual energy replacement costs at specific points along the Snake and Columbia Rivers in Washington.

Project Area	Divert from River Dam	Project Size (1000 Acres)	Energy Loss per AF diverted (KWH/AF)	Energy Used per AF diverted (KWH/AF)	Total value of energy[a] ($/AF)	Payment by agriculture[b] ($/AF)	Net Cost to Society ($/AF)
Eureka Flats	Lower Monument	109	463	1163	48.78	3.49	45.29
Horse Heaven Hills	John Day	100	222	1385	48.21	4.16	44.05
East High	Grand Coulee	385	847	698	46.35	2.09	44.26
Columbia Basin	Grand Coulee	120	847	535	41.46	1.61	39.85
Walla Walla	McNary	44	289	149	13.14	.45	12.69

[a]Based on replacement costs for energy equalling 30 mills per kwh.
[b]Based on payments for energy production at 3 mills per kwh.

For the East High Project, a proposed Bureau of Reclamation project, we assume that farm size would be restricted to 320 acres. According to Table 4, there would be an annual societal subsidy to irrigation through increased energy costs of about $50,000 per family farm.

Consider another example of a proposed 8,271 acre project in the Horse Heaven Hills, an area being developed by large corporate farms. According to the environmental impact statement for this project, it is expected to support seven farm families after full development and employ an additional 21 workers for seasonal use. Assuming, therefore, a total of 28 farm employees and a net societal cost of $154 per acre, the annual energy cost to regional utility customers would be $45,490 per farm worker. If we include induced non-farm employment by agriculture development equalling an additional 50 jobs, the energy cost per job created becomes $16,330. However, average large scale developments are expected to produce about one farm job and 1.8 off-farm jobs per 100 acres irrigated, providing a direct energy cost of $5,500 per job per year.

It is difficult to ignore these rather significant costs in determining the desirability of additional irrigation development in the state or region. It is doubtful that irrigation development would proceed at its present pace if agriculture were required to pay the full price of these energy costs.

Summary and Conclusions

System energy losses resulting from diversion of water for irrigation depend upon the amounts, timing, and location of diversions. Also, economic values of a given energy loss are influenced by the method of replacing lost energy, the time period involved, and interest rates charged for capital investments. Assumptions about these factors cannot be avoided in making such calculations. The public should be aware of such assumptions in order to form a proper judgment about the results.

It may be safely concluded that future large-scale irrigation diversions from the Columbia River system will impose significant costs on all regional residents in the eventual form of higher utility costs. This is an external cost of both private and public irrigation developments not now being considered in determining the feasibility or desirability of additional irrigation in the West.

It must be noted that any new activity causing a significant increase in demand for electricity would result in impacts similar to those of irrigated agriculture because of the policy of using average cost pricing for electricity. Agriculture, however, is unique in that water diversions for irrigation result in hydropower losses for which there is no cost recovery. In any case, all major forms of economic development should undergo similar analyses to determine regional economic impacts.

Present methods of average cost pricing in setting utility rates and water laws which disregard the opportunity costs of instream water uses provide no adequate means of internalizing such costs for decision making. The burden of energy costs resulting from future irrigation developments will almost surely be borne by all citizens rather than the direct beneficiaries of irrigation. This analysis does not prove that irrigation development would cease if such costs were internalized or that irrigation development ignoring such costs is bad or ill-conceived. However, citizens of the region should certainly become more aware of such phenomena before making decisions regarding future water allocations. Economists and policy leaders should strive to develop better mechanisms for considering costs which can be so easily documented.

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