REPORT OF THE

JOINT STANDING COMMITTEE ON ENERGY AND NATURAL RESOURCES

ON A STUDY BY THE AXIAL FLOW BULB-TYPE TURBINE SUBCOMMITTEE

November 1982

Committee Chairmen:

Senator James A. McBreairty
Representative Donald M. Hall

Members:

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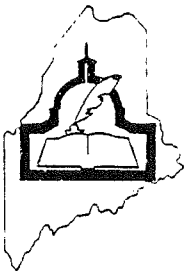
Senator Donald R. O'Leary
Representative Richard S. Davies
Representative Paul F. Jacques
Representative John M. Michael
Representative Michael H. Michaud
Representative James Mitchell
Representative Edward L. Dexter
Representative Sherry F. Huber
Representative Laurence L. Kiesman
Representative Bernard H. Austin

Legislative Assistant:
Martha Freeman



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STATE OF MAINE
ONE HUNDRED AND TENTH LEGISLATURE
COMMITTEE ON ENERGY AND NATURAL RESOURCES

January 5, 1983

Senator Charles P. Pray
Chairman
Legislative Council
State House
Augusta, ME 04333

Dear Senator Pray:

Enclosed is the final report of the Joint Standing Committee on Energy and Natural Resources on its axial flow bulb-type turbine study. This study was conducted under a Joint Order, enacted by the 110th Legislature. We hope the 111th Legislature will find this report valuable.

Sincerely,

Senator James A. McBreairty
Senate Chairman

Representative Donald M. Hall
House Chairman

enclosure
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EXECUTIVE SUMMARY

Findings

The Axial flow bulb-type turbine Subcommittee of the Joint Standing Committee on Energy and Natural Resources was established during the Second Regular Session of the 110th Legislature to study the feasibility of free stream or current-type turbines to produce hydropower in Maine. Current-type turbines extract energy from the velocity of the flow of the current of a river or stream, rather than from the fall of a head of water created by a dam. The members of the Subcommittee were: Rep. Huber and Rep. Michaud (co-chairs), Rep. Mitchell, Rep. Kiesman, Rep. Austin, and Rep. Michael. The Subcommittee presented its findings to the full Committee for further action.

The Subcommittee found:

- A study done in 1977 for one of Maine's electric utility companies suggests that current-type turbine technology may be useful for the generation of hydropower to be used as a replacement for more costly fuels during certain periods. Utility companies in Maine and Maine small hydropower developers have not, however, engaged in much investigation of this technology.

- The Federal government did provide funds for a project leading to a 1981 report on studies of certain current-type turbine devices and river sites in the United States. The report indicates that an operating, commercially viable current-type turbine system, capable of a 1 to 25 MW capacity, could be available by 1986 with continuing government funding of the project. Federal funds for the project have, however, been eliminated.

- A test of a current-type turbine device developed in Canada began in August of 1982 when a prototype of a turbodyne watermill was placed in the St. Lawrence River at Cornwall, Ontario. The prototype produces 9 KW in the 7 ft./sec. current, though its designers believe it is capable of generating 20 KW. Larger models, and models relying on 1 meter of headwater rather than only the velocity of a current, may be capable of producing megawatts. The National Research Council of Canada is continuing to fund designing and testing of these technologies by Nova Energy Limited of Dartmouth, Nova Scotia.

Recommendation

When the Subcommittee's report was presented to the Energy and Natural Resources Committee, a majority of the Committee members present voted to accept the findings and recommend to the First Regular Session of the 111th Legislature the funding, at a

cost of $25,000, of an engineering study of a few sites on Maine rivers. The purpose of the study is to determine if current-type turbines are technically and economically feasible for use in Maine to generate hydropower. The majority voting in favor of this recommendation consisted of Rep. Hall, Rep. Michaud, Rep. Mitchell, Rep. Michael, and Rep. Jacques.

Minority view

A minority of the members of the Energy and Natural Resources Committee in attendance at the presentation of the Subcommittee's findings held the view that the Committee should not recommend to the Legislature the funding of a feasibility study. The minority, consisting of Sen. McBreairty, Rep. Huber, Rep. Kiesman, and Rep. Austin, believe that the Legislature should take no further steps at this time on the current- type turbine issue, other than to make available the information gathered and findings made by the Subcommittee.

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I PURPOSE AND PROCEDURE OF STUDY

During the Second Regular Session of the 110th Legislature, Representative Donald Carter introduced a joint order requesting the Legislature to approve the appointment of a joint select committee to study the feasibility of the use of axial flow bulb-type turbines for the production of hydropower in Maine. The order stated that these types of turbines could be used without the construction of conventional dams and that the turbines permitted a high survival rate for salmon passing through them. The order requested the appropriation of $25,000 to carry out the study.

The order passed the Legislature in an amended version. The amendment required the Joint Standing Committee on Energy and Natural Resources to conduct the study, and deleted the appropriation of funds. The order directed the Committee to report its findings and any necessary legislation to the Legislative Council for submission to the First Regular Session of the 111th Legislature.

The Energy and Natural Resources Committee designated a Subcommittee of its members to proceed with the study. At the July organizational meeting of the Subcommittee written materials on bulb-type turbines were presented to the Subcommittee members. These materials were also made available to representatives in attendance from the Maine Canadian Legislative Advisory Office, Office of Energy Resources, Great Northern Paper Company, and Central Maine Power Company. These people assisted the Subcommittee throughout the study with comments on materials,

with additional materials, and with participation in the Subcommittee's discussions.

At the August meeting of the Subcommittee it became clear that some confusion existed over the subject of the study. The materials on bulb-type turbines indicated that, while tests on these turbines demonstrated an impressive survival rate for fish swimming by the installation, the turbines tested had been used in conjunction with a dam. Other materials made available by Rep. Carter evidenced an interest in other devices, sometimes called aquatic windmills, that generated hydropower from currents or tides without the use of dams. At the August meeting Rep. Carter and the Subcommittee clarified the purpose of the study: Rep. Carter's primary concern was with means of generating hydropower that did not necessitate the creation of a head of water by dam construction, that used, instead, the velocity of a river current passing through a turbine to create power. Devices operating on a velocity head are termed free stream or current-type turbines. In initially proposing the study, Rep. Carter had hoped the Legislature would appropriate funds with which the State could hire consulting engineers to do studies of some sites on Maine rivers to determine the feasibility of using current-type turbine technology to produce power. Since the initial appropriation had been amended out of the study order, Rep. Carter hoped the Subcommittee could uncover sufficient information on current-type turbines to convince them of the viability of the technology and the appropriateness of a recommendation of an engineering study for certain Maine river sites.

For its October meeting the Subcommittee had the benefit of information contained in two 1977 reports prepared for Central Maine Power Company concerning ocean and riverine current energy and wave energy, and in a 1981 report done under contract to the Department of Energy on river turbine designs. The Maine Canadian Legislative Advisory Office also supplied the Subcommitte with information on the turbodyne generator, a current-type turbine developed by Nova Energy Limited of Nova Scotia that has been tested in the St. Lawrence River at Cornwall, Ontario. Roger Farrell, vice president of Nova Energy Limited, attended the Subcommittee's final meeting in November to discuss the project.

At the end of November the Subcommittee met with other members of the Energy and Natural Resources Committee to present its findings. The findings were accepted and discussed by those Committee members in attendance. From that discussion a majority of the members present arrived at a recommendation for futher legislative action.

II FINDINGS

IN MAINE

In Alternate Electrical Energy Sources for Maine: Appendix J:Ocean and Riverine Current Energy Conversion, a report prepared in 1977 for Central Maine Power Company, the author concludes that current power may be feasible for Maine in certain circumstances. The report states that, "Ocean currents off the Maine coast are too weak to be considered as a power source, however, tidal forced river currents do offer power densities on the order of 1-5 KW per square meter of intercepted current."(at J-16). The report discusses the mechanics and efficiencies of two current-type devices: a screw turbine, similar to a windmill in design; and a Savonius rotor, an S-shaped rotor developed from a paddle-wheel design. The author found the devices to have comparable efficiency ratings (extracting between 30-45% of the total power available from a river current); the choice of device would depend, however, on a complete study of a river site. The author chose two Maine river sites for which curernt flow information was available, one on the Kennebec and one on the Piscataqua, to examine in terms of potential energy, energy extractable by a rotor, and cost of the energy extracted. The energy available in the current at the Piscataqua River site, assuming 6000 hours/year of operation, was stated to be 99 KW; in the Kennebec the amount was 12 KW. The report concluded that these energy levels did not provide an alternative to conventionally generated base-load power. The report did find, however, that current-generated power could be useful in

replacing more costly fuels during certain periods: The maximum energy from the river currents would be available at predictable times coinciding with tidal action; "fossil fuel-powered generation could be backed down when tidal current energy was being produced" (at J-15) thus saving money. The report estimated the cost of current-produced energy extracted by a rotor to be 201 mills/KWH for the Piscataqua site and 266 mills/KWH for the Kennebec site (both costs in 1986 dollars). "Generation of power in a fuel-saver mode may be considered if the estimated energy cost of 201 mills/KWH (1986 dollars) becomes competitive." (at J-16). Finally, the report simply mentions environmental concerns that should also be considered along with energy availability and cost. The concerns listed include possible danger to fish from turbine blades; esthetics of a river containing a moored structure with a curent-type device; impact on traditional uses of the river site, including boating and fishing; problems with ice; and threats to the ecosystem of the river from any change in the river's flow.

Despite the positive tone of the 1977 Central Maine Power report, hydropower developers in Maine today do not appear to be giving much consideration to hydropower devices operating on the velocity of a river's current. For example, Bob Letourneau of Central Maine Power Company stated that, while CMP had done bulb-type turbine studies for the Cold Stream potential dam site on the upper Kennebec River, the utility company had not investigated the feasibility of current-type turbines in that part of the Kennebec. The Subcommittee also contacted seven

individuals involved with small hydropower development in Maine to see if they had any experience with current-type turbines. Of the four who responded two simply stated that they had no information on these types of turbines; one offered the opinion that producing power without the the creation of a conventional head of water would be too costly; and one pointed out that a head would be created by the use of a current-type turbine without a dam, the head being even the small difference in the elevation of the water before and after passing through the turbine. These comments seem to indicate that, among these hydropower developers, current-type turbines are presumed to be less attractive than conventional hydropower devices using dams.

AT THE FEDERAL LEVEL

The Subcommittee obtained a copy of Definition of Cost Effective River Turbine Designs, the 1981 final report prepared for the Department of Energy by contractors directed to conduct studies on low pressure run-of-the-river turbines as part of the DOE's Ultra-Low Head Hydro Program. The contractors designed and evaluated a 3.05 meter (10 feet) diameter ducted turbine and a free-rotor turbine system of the same diameter. The ducted system uses a duct to increase the volume of water flowing through the turbine, while the free-rotor system is simply an underwater windmill. The capacity of the ducted system was rated at 20 KW for a current speed of 2.13 meters/second (6.98 feet/second), and the capacity of the free-rotor system was rated at 15 KW for a current speed of 3.87 meters/second (12.7 feet/second). The cost of energy produced by these systems was estimated to be less than 50 mills/KWH for an optimum river site.

The contractors for the DOE study also examined several river sites in detail, and concluded that there are many sites in the United States where curret-type turbine technology could be used. The report states that at the best river sites studied more than 2 MW rated capacity could be achieved with arrays of current-type mechanisms per kilometer of river without extracting more than 10% of the river's potential energy. Finally, the contractors recommended that the DOE continue with prototype design, testing, and pilot project phases of the program. The program goal was to have an operating, commercially viable turbine array, capable of a 1 to 25 MW capacity, by 1986. However, the Subcommittee learned that the program has not gone ahead due to the elimination of federal funding.

IN CANADA

A pilot project is underway in Canada to test the performance of a current-type turbine developed by Nova Energy Limited of Nova Scotia. The company's work has been funded by the National Research Council of Canada. The free stream turbine work is in a field testing phase: in August 1982 a vertical axis water turbine was installed in the St. Lawrence River at Cornwall, Ontario. The unit, called a turbodyne generator or watermill, employs a duct to increase the velocity of the water passing through the turbine. The unit is 4 meters wide by 3 meters long by 4.5 meters high, with a 2.4 meter diameter turbine. Two 6 meter long pontoons support the assembly anchored in the river. This free stream unit is generating, at a current speed of 7 ft./sec. at the site in which the turbine has been

placed, 9 KW of power, enough power to provide the electricity for two homes. A faster flow could produce 20 KW of power with the same model device. Larger free stream devices, as large as 13 meters wide, could generate as much as 1 MW of power. The watermill is being removed from the St. Lawrence during the winter at the direction of the NRC, to prevent possible ice damage. The designers would rather it remained in place to test the effect of ice.

Nova Energy Limited is also designing a restricted flow unit to operate on about 1 meter of head and produce up to 50 KW of power. This prototype is to be installed in a British Columbia river where it will produce the power to generate enough electricity for a small community along the river. The Canadian company's third project is to design a tidal current unit to be installed in the Bay of Fundy. Production costs of a completely installed turbodyne watermill are stated to be approximately $2000 per KW, with virtually no maintenance and an estimated life span of at least 20 years. Finally, the watermill's designers have discovered that the device is useful for simply pumping water.

III. RECOMMENDATION

A majority of the Energy and Natural Resources Committee members present at the final study meeting found that the information gathered by the Subcommittee warranted further legislative involvement in the investigation of the feasibility of using current-type or free stream hydropower technology in Maine rivers. The majority voted to recommend that the Legislature fund a study of a few specific sites on Maine rivers to determine their appropriateness for the generation of hydropower with current-type devices. The study, to be conducted by outside consultants at a cost of no more than $25,000, is to review a number of sites and narrow the number to one or two of the apparently most appropriate settings, based on readily available information on current velocity, geographic characteristics, proximity to power grids or other methods of consuming the hydropower, and the like. The second part of the study is to be an engineering feasibility assessment of these final one or two sites to determine the economic and technical feasibility of employing a prototype free stream hydropower device at these sites. The majority directed the preparation of legislation to describe and allocate funds for this study for introduction into the First Regular Session of the 111th Legislature.

The majority of the members of the Energy and Natural Resources Committee present and voting in favor of this recommendation were: Rep. Hall, Rep. Michaud, Rep. Mitchell, Rep. Michael, and Rep. Jacques.

IV. MINORITY REPORT

The minority of members of the Energy and Natural Resources Committee present at the discussion of the Subcommittee's findings and not voting to recommend further legislative action wished to enter a minority report. The minority found the information gathered by the Subcommittee useful as a resource for anyone interested in pursuing, developing, or testing current-type turbine technology; however, the minority view an investment of legislative funds in further investigation of free stream hydropower as premature. The minority believes further action should await more data from the research and testing currently going on in Canada.

The minority of the members of the Energy and Natural Resources Committee present and voting against the majority's recommendation were: Sen. McBreairty, Rep. Huber, Rep. Kiesman, and Rep. Austin.

APPENDIX A

Joint Order 1981, H.P. 2400

In House April 28, 1982

WHEREAS, the joint utilization of water resource facilities for fisheries and boating and for energy production is a desirable and possible goal; and

WHEREAS, 6 major rivers in the State contain natural runs of anadromous fisheries; and

WHEREAS, there are many more miles of undeveloped, free-flowing river corridors in the State; and

WHEREAS, there exists an axial flow bulb-type turbine that can produce required energy without the construction of a conventional-type dam; and

WHEREAS, the downstream survival rate for salmon and trout through these turbines has been recorded as high as 97%; now, therefore, be it

'Ordered, the Senate concurring, that a joint standing committee of the Legislature having jurisdiction over energy and natural resources study the feasibility of using this new type of turbine in Maine and its possible applications; and be it further

Ordered, that the committee report its findings and recommendations, together with all necessary implementing legislation in accordance with the Joint Rules, to the Legislative Council for submission in final form at the First Regular Session of the 111th Legislature; and be it further

Ordered, that the Legislative Council, before implementing this study and determining an appropriate level of funding, shall first ensure that this directive can be accomplished within the limits of available resources, that it is combined with other initiatives similar in scope to avoid implication and that its purpose is within the best interests of the State, and be it further

Ordered, upon passage in concurrence, that a suitable copy of this Order shall be forwarded to members of the committee.

APPENDIX B

STATE OF MAINE

Inter-Departmental Memorandum Date July 23, 1982

To Axial Flow Bulb-type Turbine Sub- Dept. Committee Members

From John Selser & Martha Freeman MCF Dept. Legislative Staff

Subject July 22, 1982 Organizational Meeting, minutes

The Axial Flow Bulb-type Turbine Sub-committee of the Joint Standing Committee on Energy and Natural Resources held an organizational meeting on July 22, 1982 at 1:00 P.M. in Room 135, State House, Augusta. The meeting was called to order by Senator McBreairty. The following sub-committee members were present: Representatives Bernard Austin, Laurence Kiesman, Michael Michaud, and James Mitchell. Representatives Sherry Huber and Paul Jacques were unable to attend the meeting. Representatives Huber and Michaud were elected co-chairpersons of the sub-committee.

The sub-committee heard a prepared statement by Representative Don Carter, sponsor of the study order. A brief general discussion followed his presentation. Members of the sub-committee participated in the discussion with Representative Carter and the following other interested persons: Lynwood Hand (Great Northern Paper Company), Bob Letourneau and Don Marden (Central Maine Power Company), Pam Heidell (Energy Office), and Donat Boisvert (Maine-Canadian Legislative Advisory Office).

The sub-committee decided to duplicate the written materials presented at this meeting and distribute them to all sub-committee members. Any additional materials received by the staff would be duplicated and distributed prior to the next meeting, if possible. One copy of the 1980 Report on "Survival of Downstream Migrant Echo Salmon and Steelhead Trout through Bulb Turbines" would be prepared as a reserve copy. Staff will duplicate any pages of general information which would serve to summarize the report and distribute them to the sub-committee.

Copies of this material and notices of future meetings will be made available to Senator McBreairty and other interested parties upon request. A list of these parties is attached as an appendix to these minutes.

The next meeting was scheduled for 1:00 P.M. on August 5, 1982 in Room 135 of the State House, if available (confirmation of the room will be made by staff to each sub-committee member.) The written materials will be discussed at the next meeting. Authority to invite persons in the state with a knowledge of axial flow bulb-type turbines, as resource people, was given to Representative Michaud.

The meeting was adjourned at 3:00 P.M..

attachment
JRS/elk

APPENDIX A: Interested Parties: Axial Flow Bulb-type Study

Representative Don Carter, sponsor of the study order
Box 544
Winslow, ME 04902
(send meeting notices and materials.)

Lynwood Hand, representing Great Northern Paper Company
P.O. Box 804
Houlton, ME 04730
(send meeting notices only.)

Pam Heidell
Office of Energy Resources, Station #53
State House
Augusta, ME 04333
(send meeting notices and materials.)

Paul Firlotte
Great Northern Paper Company
Millinocket, ME 04462
(send meeting notices and materials.)

Bob Letourneau
Central Maine Power Company
Edison Drive
Augusta, ME 04330
(send meeting notices only.)

Donald H. Marden, representing Central Maine Power Company
Marden, Dubord, Bernier, and Chandler
44 Elm St.
Waterville, ME 04901
(send meeting notices only.)

Jerry Poulin
Central Maine Power Company
Edison Drive
Augusta, ME 04330
(send meeting notices and materials.)

STATE OF MAINE

Inter-Departmental Memorandum Date August 18, 1982

To Axial flow bulb-type turbine Subcommittee Members Dept.

From Martha Freeman MCF Dept. Legislative Staff

Subject August 5, 1982 meeting-minutes

The Subcommittee of the Energy and Natural Resources Committee held its second meeting on August 5, 1982 at 1:00 P.M. in Room 135 of the State House. The following Committee members were present: Rep. Michaud and Rep. Huber (co-chairs), Rep. Kiesman, Rep. Austin, Rep. Mitchell, and Rep. Michael.

Others present and participating in the discussion included: Rep. Don Carter (sponsor of the study order), Pam Heidell (Energy Office), Donat Boisvert (Maine-Canadian Legislative Advisory Office), Bob Letourneau and Don Marden (CMP), David Allen (Sportsman's Alliance), and Paul McCann (Great Northern).

At the outset of the meeting, Rep. Mitchell asked Rep. Carter to summarize his hopes for the outcome of the study. Rep. Carter stated that his interest is in the generation of hydro power by means that do not require the construction of a dam. Rep. Carter's discussion began to clarify some confusion that Committee members and others had found in reviewing the materials presented at the July 22 meeting. As Bob Letourneau described it, a bulb-type turbine is a means of energy production that does necessitate construction of a dam to create the necessary head (bulb-type turbines have been shown to do less damage to fish than conventional turbines); the type of turbine Rep. Carter is concerned with operates on a velocity head, that is produces energy from the flow of the current, and does not use a dam. Bob Letourneau stated that there are none of these current-type turbines operating or being built in the United States.

Donat Boisvert indicated that the current-type turbines being designed and tried in Canada produce tidal power or energy for individual household use.

Don Marden stated that the Cold Stream potential dam site on the upper Kennebec River presents issues of economic feasibility and natural resource concerns (e.g., preservation of white water rafting) that are raised by current-type turbine possibilities. According to Bob Letourneau, CMP has done bulb-type turbine studies for the Cold Stream site, but has not investigated current-type turbines.

For the remainder of the meeting, discussion centered on speculation concerning the possible use of current-type turbines in Maine, whether or not and where sufficient flows exist in Maine waterways to make these turbines feasible. The Committee members determined that they needed more information on Maine waters and their currents, and on the functioning and practicality of current-type turbines. The Committee members requested that the following information be gathered for their next meeting:

- Pam Heidell and Rep. Carter are to choose six water sites in Maine and provide flow information on these sites.

- Pam Heidell is to provide Martha Freeman with the names of Maine hydro developers who might have knowledge of current-type turbines. Martha will contact these people.

- Don Marden is to provide Martha Freeman with the names of people to contact at the Electric Power Research Institute who might supply current-type turbine information.

- Rep. Carter is to invite someone from engineering firms he consulted in preparing the study order to attend the Subcommittee's next meeting.

- Donat Boisvert is to invite Barry Davis, a Canadian designer of a current-type turbine to attend the Subcommittee's next meeting.

The meeting of the Subcommittee concluded at 3:00 P.M.. Another meeting is to be set for some time in mid-September.

MF/elk

STATE OF MAINE

Inter-Departmental Memorandum Date October 8, 1982

To Energy & Natural Resource Committee Dept. & interested others

From Martha Freeman, Legislative Staff to the Axial flow bulb-type turbine subcommittee MCF Dept.

Subject Minutes from October 7, 1982 subcommittee meeting

The Subcommittee of the Energy and Natural Resources Committee held its third meeting on October 7, 1982 at 1:00 P.M. in Room 135 of the State House. The following Committee members were present: Rep. Huber and Rep. Michaud (co-chairs) and Rep. Kiesman. Others present included: Rep. Don Carter (sponsor of the study order), Rep. Dick Davies, Pam Heidell (Energy Office), Donat Boisvert (Maine-Canadian Legislative Advisory Office), Bob LeTourneau and Don Marden (CMP), Paul McCann (Great Northern), and Gary Higgenbottom (energy consultant).

Rep. Huber directed the groups' attention to the list of tasks set forth in the minutes for the meeting of August 5 and asked those assigned to each task to present the information they had gathered.

Rep. Carter explained his attempts to invite representatives from a national engineering firm to address the Subcommittee on current-type turbines, turbines that produce hydropower utilizing the velocity of a river's flow rather than the height of a dam-created head. Rep. Carter indicated that the firm declined his invitation due to a conflict of interest arising from its dealings with Great Northern and CMP. Paul McCann stated that he wanted to dispel any implication that Great Northern had requested the firm to make itself unavailable to the Legislature; he stated that any conflict of interest determination was made by the engineering firm alone.

Rep. Carter indicated that he had not pursued the task of meeting with Pam Heidell to develop flow information for six river sites in Maine due to his discouragement over the response of the engineering firm. Rep. Carter did supply the Subcommittee with materials describing the Archipel project in Quebec.

Donat Boisvert stated that he had been unable to invite Barry Davis, a designer of a Canadian current-type turbine, to the Subcommittee meeting because Mr. Davis was ill. Don did provide the Subcommittee with written information on a current-type turbine, developed by Nova Energy Limited of Nova Scotia (with which Mr. Davis is associated), which is now being tested at Cornwall on the St. Lawrence River.

Don Marden had provided Martha Freeman with contacts at the Electric Power Research Institute that enabled her to acquire and supply the Subcommittee with a U.S. Department of Energy report on the cost effectiveness of certain river turbine

designs not employing dams. Martha had also contacted some small hydro-power developers in Maine to solicit information on current-type turbines from them, but none she spoke with could supply any information.

The remainder of the meeting focused on a discussion of what the information received by the Subcommittee during the course of its study should lead to. Rep. Huber suggested that the Energy Office should contact the DOE to determine if any federal funding for current-type turbine projects was available (the consensus of the group was that federal funds would be scarce), and to express Maine's interest in pursuing development of its primary indigenous energy resource, hydropower, especially if technology might exist that would permit energy development compatible with recreational and other uses of the water resource. Donat Boisvert was also asked to keep informed of Canadian progress in current-type turbine development with the hope that Maine could benefit from Canadian information and experience.

The Subcommittee members present discussed what their recommendation to the full Committee should be. Rep. Kiesman expressed discomfort with recommending that the Legislature appropriate funds for a technical and economic feasibility study of certain river sites in Maine, as Rep. Carter requested, until a more definite understanding of the available current-type turbine technology could be had. Rep. Huber suggested that Rep. Carter could sponsor a bill requesting the appropriation and that the Subcommittee would supply the Energy and Natural Resources Committee with the information derived from its study. Rep. Michaud thought that perhaps the Subcommittee should recommend legislation to appropriate feasibility study funds.

The Subcommittee decided to hold its final meeting on November 5 at 1:30 P.M. to prepare its recommendation. It was hoped that the full Energy and Natural Resources Committee would meet on that same day at 2:30 P.M. to discuss the Subcommittee's work and findings.

Martha Freeman was directed to supply the Subcommittee members and interested others with copies of the Canadian materials presented by Donat Boisvert.

The meeting adjourned at 3:00 PM..

MF/elk

STATE OF MAINE

Inter-Departmental Memorandum Date November 8, 1982

To Axial flow bulb-type turbine Subcommittee & interested others

From Martha Freeman MCF Dept. Legislative Staff

Subject Minutes of Nov. 4, 1982 meeting

The Subcommittee held its final meeting on November 4, 1982 at 1:30 P.M. in Room 135 of the State House. Subcommittee members present included: Rep. Huber and Rep. Michaud (co-chairs), Rep. Austin, Rep. Kiesman, Rep. Michael and Rep. Mitchell. In the audience were Pam Heidell (OEP), Bob LeTourneau and Don Marden (CMP), Rep. Don Carter, Paul McCann (Great Northern), Donat Boisvert (Maine Canadian Legislative Advisory Office), Roger Farrell (Vice-president, Nova Energy Limited of Dartmouth, Nova Scotia), and two windmill developers from Maine.

Most of the meeting was taken up by a slide presentation and discussion by Mr. Farrell of the work his company is doing, under contract with the National Research Council of Canada, on ultra-low head hydropower. The technology Mr. Farrell is designing and testing generates power using the velocity of the current flow or, in another approach, 1 meter (approximately 3 feet) of head.

The first prototype testing of Mr. Farrell's devices occurred this summer and fall in the St. Lawrence River at Cornwall, Ontario. A turbodyne watermill, developed by Nova Energy Limited, was placed in a 7 ft./sec. current. The 9 KW produced by the device were transmitted to the local power company through nearby transmission lines. The watermill is similar to an inverted vertical axis windmill, suspended in the water from two 18 feet long pontoons, on top of which a generator sits. The 12 feet wide device was anchored to the river bed and stabilized by lines attached to bridge abutments on either side.

Mr. Farrell stated that a watermill of the prototype's size is capable of producing 20 KW in a free stream situation, 100 KW with a 1 meter head. He had hoped the prototype would be left in the water for the winter so that the effect of ice on it could be tested; the Research Council is afraid of damage, however, and is having the watermill taken out of the river soon.

According to Mr. Farrell, a 2-3 meter/sec. current is necessary for efficient operation of the watermill; a 1 meter head (but not more than 1.5 meters) is the optimum condition. He estimates the installed cost of the prototype device to be about $2000/KW. The life span of the device is at least 20 years with virtually no maintenance. Fish would, he believes, have no trouble surviving a swim through or around the installation.

Mr. Farrell sees watermill technology as having several applications. One application could be as a device supplying the total electricity (as much as 50 KW) needed by a small community. A larger model of the watermill, at least 40 feet wide, could produce MW power to be used by a city or added to a power company's grid. The watermill is also useful for simply pumping water.

After Mr. Farrell's presentation, the Subcommittee and audience discussed ways in which watermill technology could be used in Maine. Of particular interest is the possibility that watermills could be installed near abandoned dams, where some small head still exists.

The Subcommittee concluded the meeting by voting to present a report containing findings but no recommendations to the full Energy and Natural Resources Committee. Three Subcommittee members supported the idea of recommending that the Legislature appropriate $20-30,000 to fund a feasibility study of a few river sites in Maine; the three other members present did not agree with such a recommendation. The Subcommittee adjourned at 4:00 P.M., intending to meet with the full Committee on November 30 to discuss its findings and possible recommendations to the Legislature by the Committee.

MF/elk

APPENDIX C

ALTERNATIVE ELECTRICAL ENERGY SOURCES FOR MAINE

W.J. Jones M. Ruane

Appendix J
OCEAN AND RIVERINE CURRENT ENERGY CONVERSION

J. Mays

Prepared for the Central Maine Power Company.

Report No. MIT-E1 77-010
MIT Energy Laboratory
July 1977

This appendix is one of thirteen volumes; the remaining volumes are as follows: A. Conversion of Biomass; B. Conservation; C. Geothermal Energy Conversion; E. Ocean Thermal Energy Conversion; E. Fuel Cells; F. Solar Energy Conversion; G. Conversion of Solid Wastes; H. Storage of Energy; I. Wave Energy Conversion; K. Wind Energy Conversion, and L. Environmental Impacts.

Table 4.1

Estimated Current Device Costs

COSTS: (1986 dollars)	"Piscataqua" $1000	"Kennebec" $1000
rotor	$ 325.7	$ 43.9
generator	140.0	29.6
transmission to shore	32.4	4.1
(1) Subtotal	$ 498.1	$ 77.6
operation and maintenance @ 6% of (1) per year	29.9	4.7
levelized annual capital charges for (1) at 18%	89.7	14.0
Total annual costs	119.6	18.7
electrical energy per year	595.3 MWH/year	70.2 MWH/year
ENERGY COST (1986 dollars)	201 mills/KWH	266 mills/KWH

5.0 ENVIRONMENTAL IMPACTS

The use of either a Savonius rotor or a multibladed turbine will probably have similar effects on the environment. The turbine will have higher tip speeds thus posing some possibility of danger to fish.

The moored structure will not add to the esthetics of the river but to the extent that moored ships degrade the view, the insult will be minimal.

The siting should obviously be done to minimize the impact upon the environment and traditional uses of the site such as navigation, fishing, pleasure boating, etc. Some rivers like the Kennebec have quite a lot of ice which would pose a problem.

The greatest direct threat stems from the fact that as energy is absorbed the current is diminished. In Technical Note B it is derived that optimum extraction would diminish the local current by one third. However, the whole river is not going to be tapped, just some fraction. Obviously the more devices that are emplaced, the more the flow will be retarded.

An important element of an environmental statement for a proposed site would be just how the river flow would be affected and hence the ecosystem the river supports.

6.0 CONCLUSION

Ocean currents off the Maine coast are too weak to be considered as a power source, however, tidal forced river currents do offer power densities on the order of 1 - 5 KW per square meter of intercepted current. The power output varies as the cube of the current velocity and depends primarily on the tidal cycle. Consideration of current power on a base-loaded mode is not likely due to the periodicity and small power density. Generation of power in a fuel-saver mode may be considered if the estimated energy cost of 201 mills/KWH (1986 dollars) becomes competitive.

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DEFINITION OF COST EFFECTIVE RIVER TURBINE DESIGNS

FINAL REPORT
FOR THE PERIOD SEPTEMBER 30, 1980 - DECEMBER 31, 1981

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DECEMBER 1981

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Prepared for the
U.S. Department of Energy
Under Contract No. DE-FC07-80ID12204

EXECUTIVE SUMMARY

General

AeroVironment Inc. (AV) has been studying low pressure run-of-the-river turbines as part of U.S. Department of Energy's (DOE) Ultra-Low Head Hydro Program, under Cooperative Agreement No. DE-FC07-80ID12204 entitled, "Definition of Cost Effective River Turbine Designs." These river turbine units will operate on the equivalent of less than 0.2 m (7 in) of head, and in a river with a reasonable current resource, the units are estimated to produce cost-effective electricity.

Two system concepts have been evaluated in this study: (1) a ducted turbine system, and (2) a free-rotor system. The ducted turbine uses an augmenter duct to increase volume flow through the turbine rotor, thus enhancing cost-effectiveness and mimimizing the turbine rotor diameter required for a given resource and rated power. The free-rotor system is essentially an underwater windmill and offers the potential for simplicity and lower system cost than for the ducted system.

The ducted river turbine design consists of an augmenter duct, a rotor with two cantilevered blades, a nacelle containing a gearbox and electrical generating equipment, a rigid mooring system, and an electrical power transmission system. The free-rotor river turbine has no augmenter duct and the rotor blades are larger than those for the ducted system. Internal features are similar to those of the ducted rotor system.

Program Results

The program consisted of the following tasks: (1) define river current resources, (2) design ducted and free-rotor systems and develop performance estimates, (3) determine system cost estimates and conduct an economic analysis, and (4) conduct a model test program to substantiate duct augmentation.

The overall conclusion is that both ducted and free-rotor turbine systems can produce cost-effective electricity. The optimum 3.05-m (10-ft) ducted unit was rated at 20 kW for a current speed of 2.13 m/s (6.98 ft/s), with an installed system cost of $12,200. The optimum 3.05-m (10-ft) free-rotor unit was rated at 15 kW for a current speed of 3.87 m/s (12.7 ft/s), with an installed system cost of $9,740. With operating and maintenance costs estimated to be $1,000 per year, the cost of energy for either unit was determined to be less than 50 mills/kWh, when the units were operated in flows with current resources corresponding to the better rivers studied.

- Definition of River Current Resource

A number of sites on the Snake, Columbia, Sacramento, and Mississippi rivers were studied in detail. Suitable sites were identified and it was concluded that there are many river sites in the United States where run of the river turbine installations appear practical. At the best sites studied, more than 2 MW rated capacity could be obtained from arrays per kilometer of river, with less than 10% of the river potential energy extracted.

o Configuration Design and Performance

The approach taken for the design study was to compare ducted and free-rotor systems at 3.05 m (10 ft) diameters, with the rated power left as a variable. After determining the performance in terms of the annual average power delivered as a function of rated power, the determination of the optimum rated power was left for the economic analysis. To keep the units simple and inexpensive, only passive power limiting by progressive blade stall was considered in the design, so that active control systems are not required.

Using AV's rotor and duct analysis techniques, the energy capture of both systems was calculated for three representative current resources. The free-rotor obtained a higher average capacity factor, since passive power limiting through blade stall allowed the unit to continue producing power in very high flow conditions. The ducted unit was designed to cut-out in high-flow conditions because it could not be designed to satisfactorily self-limit power production in high flow conditions to avoid overpowering the generator.

o Cost Estimates and Economic Analysis

Cost estimates were developed for both systems. An analysis of the cost and performance estimates showed that either configuration can produce electricity at less than 50 mills/kWh with the better river resources, using a conservative fixed-charge rate of 0.18. This is certainly an indicator that units can be produced and operated cost-effectively in the utility environment as an alternative to new conventional generating capacity. However, a more complete economic study, including life-cycle costs, cash flow analyses, and consideration of tax implications will be required to determine the desirability of the river turbine concept to an investor-owned utility.

o Test Program to Substantiate Duct Augmentation

A high augmentation ducted turbine model with an exit diameter of 0.40 m (15.75 in) was tested in the Iowa Institute of Hydraulics Water Channel to substantiate the augmentation level of the design duct. After several modifications, the duct achieved more than 80% of its design performance, which was encouraging, given the relatively low Reynolds number of the model test. It is felt that with additional design and testing, the design augmentation can be achieved. The model tests demonstrated ducted turbine performance which was better than the performance expected for a free-rotor system of the same exit area.

Conclusions and Recommendations

The costs of energy calculated for the two systems are essentially the same, given the uncertainties at this level of analysis. However, the technical risk associated with the ducted turbines appears higher than for the free-rotor turbines. Therefore, the free-rotor system configuration should be developed.

AeroVironment recommends continuing with a program plan aimed at developing an operating 1 to 25 MW turbine array pilot program by FYE 1986. The next program phase, Phase II, should provide for the design and construction of a prototype unit. The Phase III program should be an in-service test program designed to establish O&M costs and system lifetime. The Phase IV program should be a pilot project to establish a 1 to 25 MW river turbine installation at a commercially viable site.

MAINE-CANADIAN LEGISLATIVE
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EXTRACTING ENERGY FROM RIVER AND TIDAL CURRENTS USING OPEN AND DUCTED VERTICAL AXIS TURBINES

THE TURBODYNE GENERATOR

For The Conference On
New Approaches to Tidal Power
June 1 to 3, 1982

By

Barry V. Davis
and
David H. Swan

NOVA ENERGY LIMITED
DARTMOUTH, NOVA SCOTIA

4. CONCLUSIONS

The Turbodyne Generator provides a viable solution for the economic extraction of useful energy from rivers and tidal estuaries. Two basic types of Turbodyne Generator have been developed, the free stream type (ie. no dam) is designed for use in relatively swift flowing rivers or tidal currents with speeds above 2 m/s, while the restricted flow type is designed for use in some form of barrage. The barrage would be designed to provide a total operational head difference across the turbine of between 0.5 m and 2.0 m.

At our present level of knowledge, Turbodyne Generators in the range of 10 kW in a free stream installation to 10 MW in a restricted flow installation, appear to be technically and economically feasible.

The following unique characteristics give significant advantages to the Turbodyne Generator when it is used in tidal applications:

1. Minimal effect on the tidal range and therefore minimal environmental impact (Ref. 8).

2. Unlikely to cause major alterations to siltation patterns.

3. No sluice gates or de-watering gates are required.

4. Civil Engineering requirements are significantly less than for conventional tidal power schemes.

5. Ultra low head which has been considered to be unsuitable for conventional hydropower development may become feasible with the Turbodyne Generator.

6. Lower power units are used relative to bulb turbines (or similar) because the Turbodyne Generator produces power in both ebb and flood tides (rotational direction unchanged) at a lower head difference for a longer period, to give similar tidal cycle output. This characteristic means smaller energy storage requirements and reduces the problems associated with grid interconnect management procedures.

7. The Vertical Axis design allows the generator and transmission system to be mounted above the turbine in an unpressurized and easily accessible area.

8. Based on the above characteristics it is clear that the total installed cost per average kW-h of a Turbodyne Generator may be significantly less than for a Bulb Turbine or similar conventional tidal power installation.

Further work is planned for the design, development, manufacturing and field testing of a 200 kW unit in 1982-1983 and a 1 MW unit in 1983-84, in addition to the three 10 kW to 50 kW units discussed earlier. It is expected that these activities will lead to increased knowledge of manufacturing costs, market opportunities, installation and operational costs.

APPENDIX D

RESOLVE, Authorizing and Directing the Joint Standing Committee on Energy and Natural Resources to Contract for an Engineering Study of Maine River Sites to Determine the Feasibility of Current-type Turbines for Hydropower Production.

Emergency preamble. Whereas, an engineering feasibility study of certain Maine river sites to determine the usefulness of current-type turbine technology for hydropower generation should examine river sites in various seasons; and

Whereas, the members of the Joint Standing Committee on Energy and Natural Resources who will contract for this study will be able to carry out their responsibilities most easily while the Legislature is in session and the members are available to meet; and

Whereas, in the judgment of the Legislature, these facts create an emergency within the meaning of the Constitution of Maine and require the following legislation as immediately necessary for the preservation of the public peace, health and safety; now, therefore, be it

Current-type turbines; engineering feasibility study. Resolved: That the Joint Standing Committee on Energy and Natural Resources is directed to appoint a subcommittee of its members to contract for an engineering study of a few Maine river sites to determine the feasibility of using current-type turbines to produce hydropower at some sites.

The current-type turbine technology studied shall be a device or devices capable of generating hydropower from the velocity of a river's current without using conventional dams to create headwater or using an ultra-low head of water.

The study shall begin by using available data on current flow, geographic characteristics, and the like to narrow the investigation to a few appropriate Maine river sites. These sites shall be examined with the result of one or two sites being finally chosen for the engineering feasibility study. The engineering feasibility study shall define and cost the installation of a prototype current-type turbine at the particular site or sites.

Proposals; report. Resolved: That the subcommittee appointed by the Joint Standing Committee on Energy and Natural Resources shall request proposals for the conduct of the study, shall review the proposals submitted and shall contract for performance of the study. The subcommittee shall:

1. Approve the detailed work plan for the study;

2. Conduct general oversight of the study;

3. Examine the results of the study; and

4. Report, by November 1, 1983, their conclusions and any recommendations for future legislative action to the Joint Standing Committee on Energy and Natural Resources.

Legislation. Resolved: That the Joint Standing Committee on Energy and Natural Resources report any necessary implementing legislation arising from the study to the Legislative Council for introduction at the Second Regular Session of the 111th Legislature.

Allocation. Resolved: That $25,000 be allocated from the Legislative Account to carry out this study.

Emergency clause. In view of the emergency cited in the preamble, this resolve shall take effect when approved.

STATEMENT OF FACT

This resolve arises from a study conducted by the Energy

and Natural Resources Committee of current-type turbine devices that produce hydropower using the velocity of waterflow rather than the fall of headwaters created by a dam. The Committee found in its study that viable current-type turbine technology exists and may have some application in Maine. The purpose of this resolve is to authorize and fund the next phase of the investigation of this technology, an engineering feasibility study of specific Maine river sites.