HB

191

<target><bill>HB 191</bill><subject>HB 191</subject><comm>HENE26</comm></target>

26-LS0185\E
Kane
4/7/09

CS FOR HOUSE BILL NO. 191( )

IN THE LEGISLATURE OF THE STATE OF ALASKA

TWENTY-SIXTH LEGISLATURE - FIRST SESSION

BY

Offered:
Referred:

Sponsor(s): REPRESENTATIVES JOHNSON, Keller

A BILL

FOR AN ACT ENTITLED

"An Act relating to nuclear energy production and transportation of nuclear waste material; amending the definition of 'power project' or 'project' as it relates to rural and statewide energy programs and the Alaska Energy Authority; relating to the alternative energy revolving loan fund and amending the definition of 'alternative energy system' as it relates to that fund and to the conservation of energy and materials; and providing for an effective date."

BE IT ENACTED BY THE LEGISLATURE OF THE STATE OF ALASKA:

*** Section 1.** AS 18.45.020 is amended to read:

Sec. 18.45.020. United States licenses or permits required. A person may not manufacture, construct, produce, transfer, acquire, or possess a special nuclear material facility, by-product material facility, production facility, or utilization facility, or act as an operator of a production facility or utilization facility, wholly within the state without first obtaining a license or permit for the activity in which the person proposes to engage from the Nuclear Regulatory Commission if the commission requires a license or permit to be obtained by persons proposing to engage in the activities.

* **Sec. 2.** AS 18.45.025 is amended to read:

Sec. 18.45.025. Facilities siting permit required. (a) A person may not construct a nuclear fuel production facility, **nuclear utilization or** utilization facility, reprocessing facility, or nuclear waste disposal facility in the state without first obtaining a permit from the Department of Environmental Conservation to construct the facility on land designated by the legislature under (b) of this section.

(b) The legislature shall designate by law the land in the state on which a nuclear fuel production **facility**, nuclear utilization **facility**, [NUCLEAR] reprocessing **facility**, or nuclear waste disposal facility may be located. In designating the land in the state on which

(1) a nuclear utilization facility or utilization facility may be located, the legislature shall act in the interest of regulating the economics of nuclear energy;

(2) a nuclear fuel production **facility**, [NUCLEAR UTILIZATION,] nuclear reprocessing **facility**, or nuclear waste disposal facility may be located, the legislature shall act to protect the public health and safety.

(c) The Department of Environmental Conservation shall adopt regulations governing the issuance of permits required by (a) of this section. [HOWEVER, A PERMIT MAY NOT BE ISSUED UNTIL

(1) REPEALED

(2) THE MUNICIPALITY WITH JURISDICTION OVER THE PROPOSED FACILITY SITE HAS APPROVED THE PERMIT; AND

(3) REPEALED

(4) THE GOVERNOR HAS APPROVED THE PERMIT.]

* **Sec. 3.** AS 42.45.990(4) is amended to read:

(4) "power project" or "project" means a plant, works, system, or facility, together with related or necessary facilities and appurtenances, including a divided or undivided interest in or a right to the capacity of a power project or project,

that is used or is useful for the purpose of

(A) electrical or thermal energy production [OTHER THAN NUCLEAR ENERGY PRODUCTION];

(B) waste energy utilization and energy conservation; or

(C) transmission, purchase, sale, exchange, and interchange of electrical or thermal energy, including district heating or interties;

*** Sec. 4.** AS 44.83.990(6) is amended to read:

(6) "power project" or "project" means a plant, works, system, or facility, together with related or necessary facilities and appurtenances, including a divided or undivided interest in or a right to the capacity of a power project or project, that is used or is useful for the purpose of

(A) electrical or thermal energy production [OTHER THAN NUCLEAR ENERGY PRODUCTION];

(B) waste energy utilization and energy conservation; or

(C) transmission, purchase, sale, exchange, and interchange of electrical or thermal energy, including district heating or interties;

*** Sec. 5.** AS 45.88.010(a) is amended to read:

(a) There is established in the Department of Commerce, Community, and Economic Development the alternative energy revolving loan fund to carry out the purposes of AS 45.88.010 - 45.88.090. Loans made under AS 45.88.010 - 45.88.090 are to be used to develop means of energy production utilizing energy sources [OTHER THAN FOSSIL OR NUCLEAR FUEL], including [, BUT NOT LIMITED TO,] windmills, water**<u>, nuclear fuel,</u>** and solar energy devices.

*** Sec. 6.** AS 45.88.010 is amended by adding a new subsection to read:

(e) The fund consists of

(1) money appropriated to the fund by the legislature;

(2) gifts, bequests, or contributions from other sources; and

(3) principal and interest payments or other income earned on loans or investments in the fund and appropriated to the fund.

*** Sec. 7.** AS 45.88.030 is amended by adding new subsections to read:

(f) A loan must be secured by a mortgage or other security instrument in the real property to be improved, and a lien on the improvements financed under AS 45.88.010.

(g) The interest rate

(1) may not exceed the maximum rate of eight percent a year and may not be less than five percent a year;

(2) shall be established by the department based on the bank prime rate listed in the Wall Street Journal during the previous quarter plus one percentage point, set to the nearest one-half point for loans made; and

(3) set for a quarter remains in effect until the department changes the rate.

* **Sec. 8.** AS 45.88.090(a) is amended to read:

(a) In AS 45.88.010 - 45.88.090, "alternative energy system"

(1) means a source of thermal, mechanical, or electrical energy **that may be** [WHICH IS NOT] dependent on [OIL OR GAS OR] a nuclear fuel for the supply of energy for space heating and cooling, refrigeration and cold storage, electrical power, mechanical power, or the heating of water;

(2) includes

(A) an alternative energy property as defined by 26 U.S.C. 48(a)(3)(A) (sec. 301, P.L. 95-618, Internal Revenue Code);

(B) a method of architectural design and construction **that** [WHICH] provides for the collection, storage, and use of direct radiation from the sun;

(C) a woodstove with a catalytic converter or a catalytic converter for a wood stove; and

(D) a steam, hot water, or ducted hot air central heating system that uses wood or coal for fuel;

(3) does not include

(A) a stove that uses only **wood or coal** [WOOD, COAL, OR OIL] for fuel; or

(B) a fireplace or fireplace insert.

* **Sec. 9.** AS 46.11.900(1) is amended to read:

(1) "alternative energy system"

(A) means a source of thermal, mechanical, or electrical energy that **may be** [IS NOT] dependent on [OIL OR GAS OR] a nuclear fuel for the supply of energy for space heating and cooling, refrigeration and cold storage, electrical power, mechanical power, or the heating of water;

(B) includes

(i) an alternative energy property as defined by 26 U.S.C. 48(a)(3)(A); and

(ii) a method of architectural design and construction that provides for the collection, storage, and use of direct radiation from the sun;

* **Sec. 10.** AS 18.45.027; AS 45.88.010(c), 45.88.030(e), and 45.88.040(a) are repealed.

* **Sec. 11.** This Act takes effect immediately under AS 01.10.070(c).

ALASKA STATE LEGISLATURE

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716 West 4th Avenue, Suite 640
Anchorage, Alaska 99501
Phone (907) 269-0200
Fax (907) 269-0204
Rep.Craig.Johnson@legis.state.ak.us

Session:
State Capitol, Room 126
Juneau, Alaska
99801-1182
Phone (907) 465-4993
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REPRESENTATIVE CRAIG JOHNSON
HOUSE DISTRICT 28

Sponsor Statement
Nuclear Energy
HB 191

The State of Alaska is unmatched in its size and diversity. From the rain forest of SE to the barren tundra in the north, from the boreal forest of the Interior to the windswept Aleutian Islands Alaska's geology is extremely diverse.

The potential for energy projects is just as diverse. Some areas of the State have the potential for Hydroelectric Facilities, other areas have an abundance of gas and/or crude oil, there are areas where Geothermal looks promising, some places where there is wind potential and the possibilities abound.

The important thing is that each community or region has an opportunity to make an informed decision about the alternative that is right for their constituents. Policies that either restrict the options or entice communities into plans that are not financially sustainable do not lead to a stable, sustainable State energy policy.

HB 191 removes the restrictions on the use of Nuclear power. It does not advocate nuclear above other energy sources. It simply levels the playing field so that a community or region may consider this source of power along with other sources. This bill also expands the definition of alternate energy as it applies to the energy loan fund to permit selection of the technology that best applies to each individual situation.

It is imperative that the States energy policy be as diverse as the State. While there are some that advocate a restricted portfolio of energy sources, history shows that this plan of action leads to more volatility and eventually to shortages. Passing this legislation, Alaska is insuring that there are numerous energy solutions.

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REPRESENTATIVE CRAIG JOHNSON
HOUSE DISTRICT 28

Changes between HB 191\R and CS for HB191\E

The changes from HB 191\R to CS for HB 191\E incorporate some of Division of Investments recommendations and corrects a drafting error.

<u>Section 1</u> of the CS amends AS18.45.020 to add the word “facility in a number of places. **No change between HB 191 and CS for HB 191.**

<u>Section 2</u> of the bill amends AS 18.45.025 to state that when the legislature designates by law the land in the state on which a nuclear utilization facility or utilization facility may be located, it must act only in the interest of regulating the economics of nuclear energy. This section also deletes portions of AS 18.45.025 © that state that a permit may not be issued unless approved by the municipality and the governor. **No change between HB 191 and CS for HB 191.**

<u>Section 3</u> amends the definition of “power project or “project in AS 42.45.990 (4) to delete the exclusion of nuclear energy from the definition. **No change between HB 191 and CS for HB 191.**

<u>Section 4</u> amends the definition of “power project” or “project” in AS 44.83.990 (6) **No change between HB 191 and CS for HB 191.**

<u>Section 5</u> of the bill amends AS 45.88.010(a) to delete the exclusion of nuclear fuel energy sources for possible loans from the alternative energy loan fund and include nuclear fuel to the list of acceptable energy sources. **No change between HB 191 and CS for HB 191.**

<u>Section 6</u> Adds language allowing a variety of capitalization sources for the Alternative Energy Revolving Loan Fund.

Also stipulates that principal and interest payments and other income on loans or investments in the fund become part of the fund. **This is change between HB 191 and CS for HB 191. The language was taken from HB 196.**

<u>Section 7</u> Adds new subsections to AS 45.88.030 requiring a loan be secured on he real property to be improved and on the first lien on the improvements financed under the loan.

States that the interest rate will be set between 5% and 8%, declares how the specific rate will be calculated in relation to the bank prime rate, and describes the length of time that the rate remains in effect. **This is change between HB 191 and CS for HB 191. The language was taken from HB 196.**

<u>Section 8</u> of the bill amends the definition of "alternative energy system" in AS 45.88.090(a) to conform with the changes made in section 5 of the bill. **No change between HB 191 and CS for HB 191 except:**

1. the words "oil or gas or" are deleted on page 4 line 14 of CS to HB 191. The draft of the bill had new technology for oil and gas. When a definition could not be formulated for new technology the decision was made to take it out. The drafter took out new technology but not oil or gas or from page 3 line 27 of HB 191
2. the word oil is removed from page 4 line 29 of the CS to HB 191 shown on page 4 line 10 of HB 191

<u>Section 9</u> of the bill amends the definition of "alternative energy system" in AS 45.11.900(1) to match the definition, as amended in sec. 8 of the CS. **No change between HB 191 and CS for HB 191 except:**

- the words "oil or gas or" are deleted on page 5 line 3 of CS to HB 191. The draft of the bill had new technology for oil and gas. When a definition could not be formulated for new technology the decision was made to take it out. The drafter took out new technology but not oil or gas or from page 4 line 15 of HB 191.

<u>Section 10</u> repels AS 45.88.01.0(c), 45.88.030(e) and 45.88.040(a). **This is change between HB 191 and CS for HB 191. The language was taken from HB 196.**

<u>Section 11</u> sets an immediate effective date. **No change between HB 191 and CS for HB 191.**

FISCAL NOTE

STATE OF ALASKA		Fiscal Note Number:	
2009 LEGISLATIVE SESSION		Bill Version:	**HB 191**
		() Publish Date:	

Identifier (file name): HB 191-CED-AEA-04-08-09

Title	ACT RELATING TO NUCLEAR ENERGY PRODUCTION	Dept. Affected:	DCCED
		RDU	Alaska Energy Authority
		Component	AEA Rural Energy Operations
Sponsor	Representatives Johnson and Keller		
Requester	House Energy Committee	Component Number	2600

Expenditures/Revenues (Thousands of Dollars)

Note: Amounts do not include inflation unless otherwise noted below.

	Appropriation Required	Information					
OPERATING EXPENDITURES	**FY 2010**	**FY 2010**	**FY 2011**	**FY 2012**	**FY 2013**	**FY 2014**	**FY 2015**
Personal Services							
Travel							
Contractual							
Supplies							
Equipment							
Land & Structures							
Grants & Claims							
Miscellaneous							
TOTAL OPERATING	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
CAPITAL EXPENDITURES							
CHANGE IN REVENUES ( )							

FUND SOURCE (Thousands of Dollars)

1002 Federal Receipts							
1003 GF Match							
1004 GF							
1005 GF/Program Receipts							
1037 GF/Mental Health							
Other Interagency Receipts							
TOTAL	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

Estimate of any current year (FY2009) cost: 0.0

POSITIONS

Full-time							
Part-time							
Temporary							

ANALYSIS: *(Attach a separate page if necessary)*

The bill changes the definition of a power project relative to the power project fund to include nuclear production.

Alaska Energy Authority's (AEA) fiscal note is zero, because there are currently no projects of this type.

AEA estimates that annual operating costs would increase by $365,000 for each nuclear power project that has to be managed; $165,000 for a project manager with technical nuclear knowledge and $200,000 for contractua advisory service in the field.

Prepared by:	Linda MacMillan - AEA Project Accountant	Phone	907-771-3029
Division	Alaska Energy Authority	Date/Time	4/7/09 3:30 PM
Approved by:	Emil Notti, Commissioner	Date	4/7/2009
	Department of Commerce, Community and Economic Development		

(Revised 9/10/2008 OMB)

FISCAL NOTE

STATE OF ALASKA
2009 LEGISLATIVE SESSION

Fiscal Note Number:
Bill Version: **HB191**
() Publish Date:

Identifier (file name): HB191-DFG-DAS-04-07-09
Title: An act relating to nuclear energy production and transportation
Sponsor: Johnson, Keller
Requester: House Special Committee on Energy, Resources
Dept. Affected: Fish and Game
RDU: Administration and Support
Component: Administrative Services
Component Number: 479

Expenditures/Revenues (Thousands of Dollars)

Note: Amounts do not include inflation unless otherwise noted below.

	Appropriation Required	Information					
OPERATING EXPENDITURES	**FY 2010**	**FY 2010**	**FY 2011**	**FY 2012**	**FY 2013**	**FY 2014**	**FY 2015**
Personal Services							
Travel							
Contractual							
Supplies							
Equipment							
Land & Structures							
Grants & Claims							
Miscellaneous							
TOTAL OPERATING	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
CAPITAL EXPENDITURES							
CHANGE IN REVENUES ( )							

FUND SOURCE (Thousands of Dollars)

1002 Federal Receipts							
1003 GF Match							
1004 GF							
1005 GF/Program Receipts							
1037 GF/Mental Health							
Other Interagency Receipts							
TOTAL	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

Estimate of any current year (FY2009) cost: ______

POSITIONS

Full-time							
Part-time							
Temporary							

ANALYSIS: *(Attach a separate page if necessary)*

No fiscal impact to department.

Prepared by: John White, Procurement Specialist V
Division: Administrative Services
Approved by: Tom Lawson, Director of Administrative Services
Department of Fish and Game

Phone: 907-465-6178
Date/Time: 4/7/09 1:20 p.m.
Date: 4/7/2009

Galena Nuclear Project

M :T Solutions LLC

- 2003
  Initial contact with Toshiba
- 2004
  DOE report recommended evaluation of 4S as the Galena Energy source (Situational Analysis)
  City Counsel passed resolution to pursue siting a 4S based facility in Galena.
- 2005
  Galena's meeting with NRC
  Request funding for white papers

M:T Solutions LLC

Galena Continued

- 2006
  White papers funding authorized by State of Alaska
  White papers completed
- 2007
  Toshiba meets with the Nuclear Energy Authority to discuss licensing the Toshiba 4S Reactor

Nuclear Energy

Questions:

1. What about 3 mile Island

3. What about Terrorists

5. What happens to the waste

7. How do you handle an emergency

Nuclear Battery

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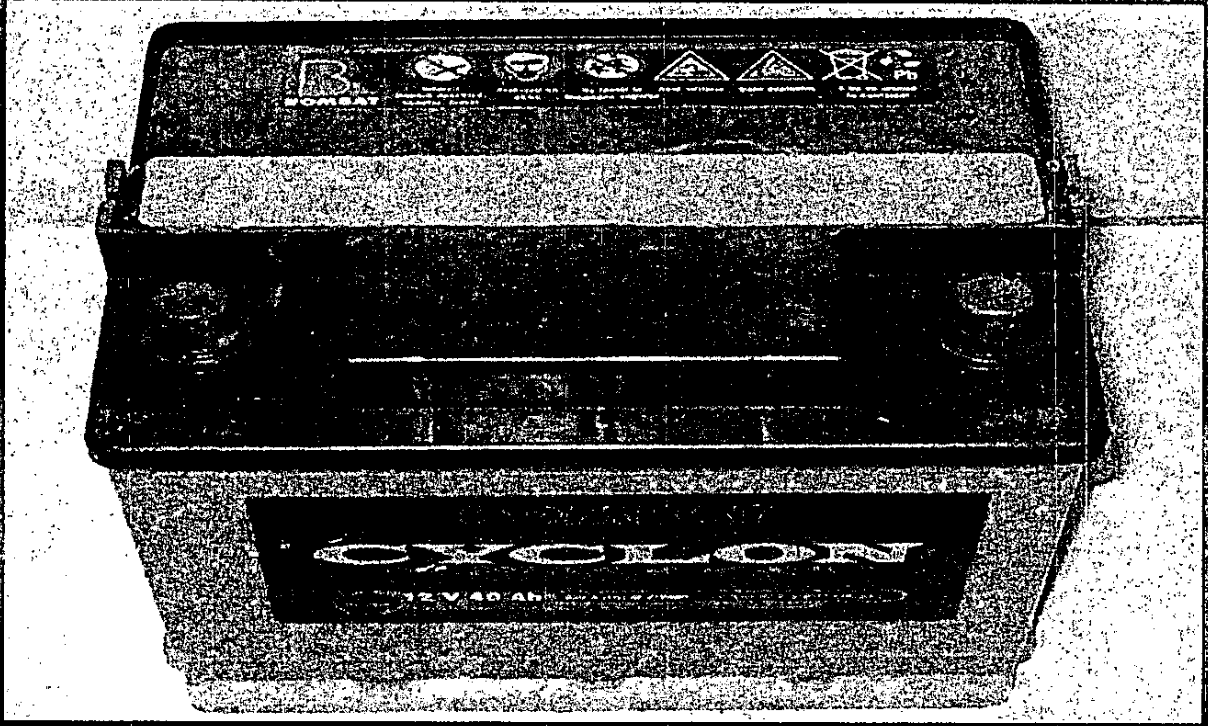
- Battery



Plant Description

- Reactor
  - Core

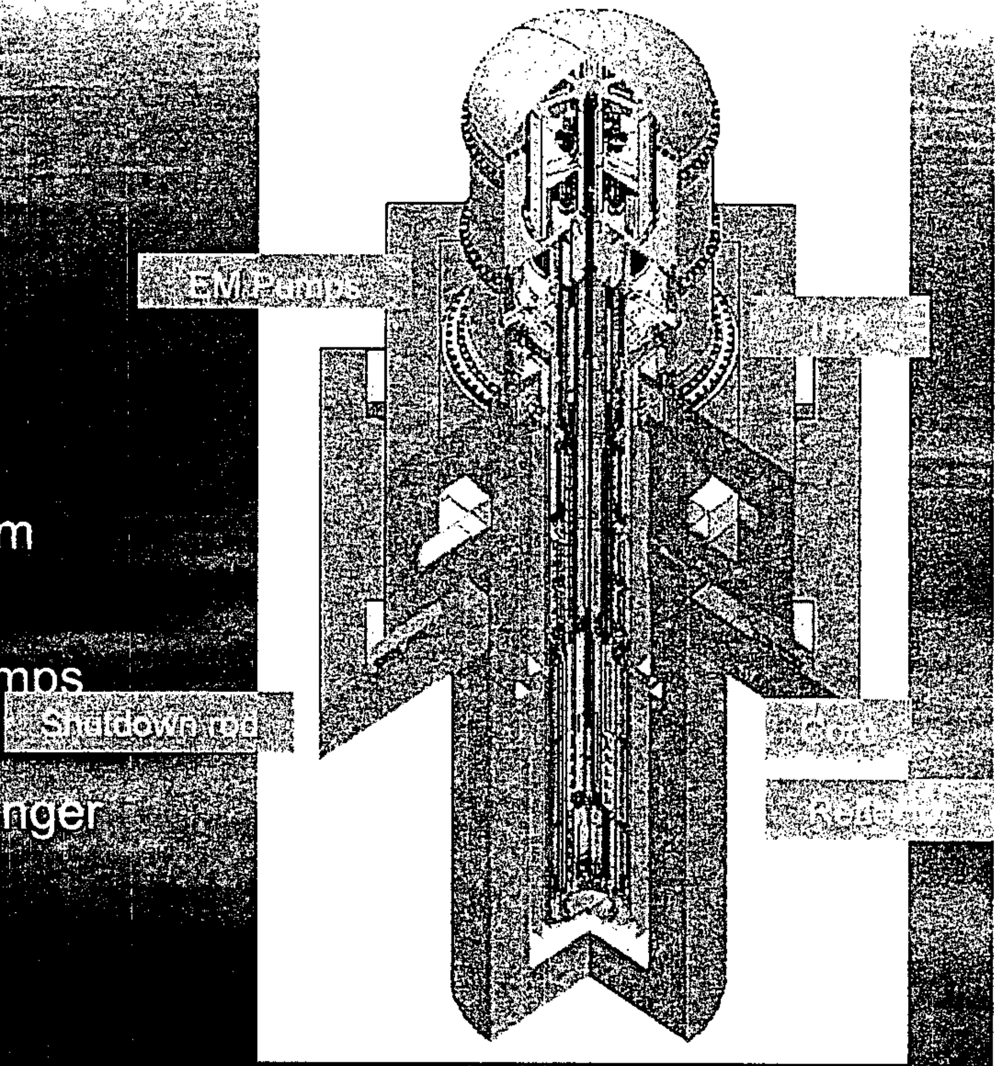
    Metallic fuel core (U-10%Zr)
  - Reactivity control

    Movable reflectors
  - Shutdown system

    Shutdown rod and reflectors
  - Primary heat transport system
    - Pumps: Annular type

      Electro-magnetic (EM) pumps
    - IHX: Annular type

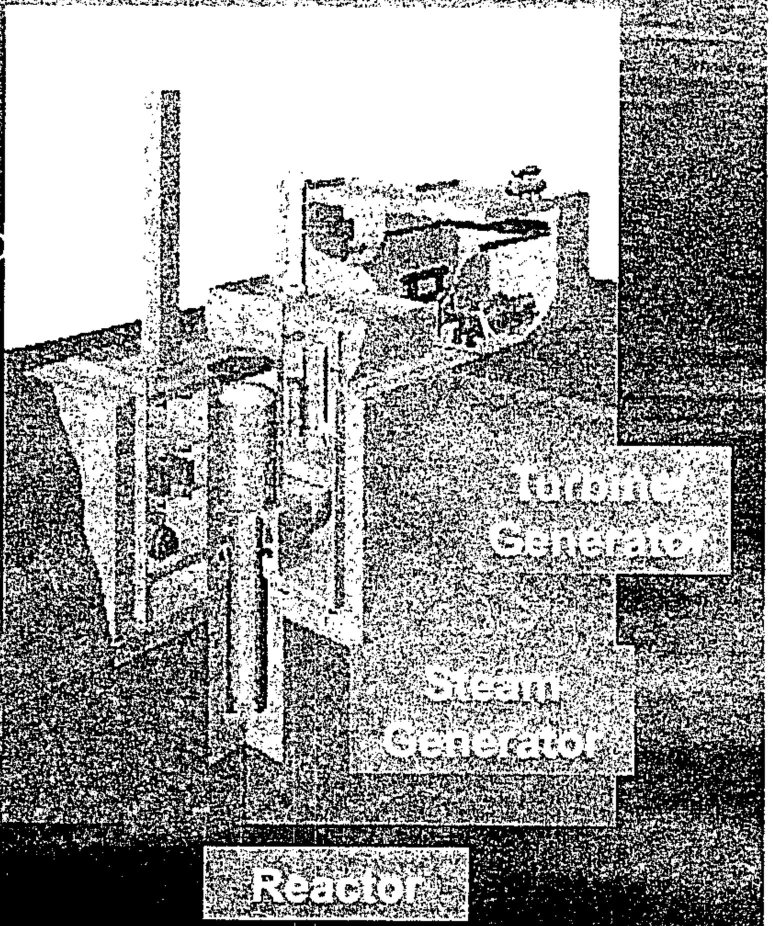
      intermediate heat exchanger



Overview

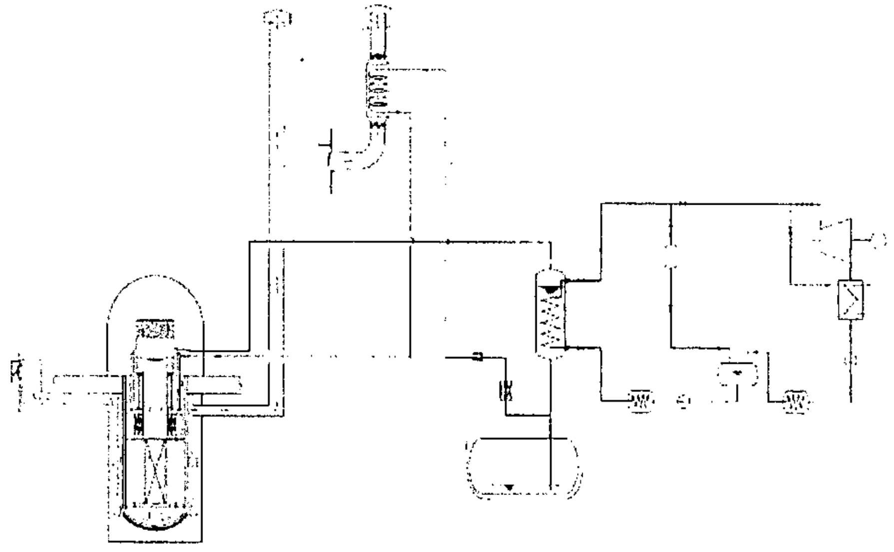
Sodium cooled fast reactor

- 30 MWt (10MWe)
- Application
  - Remote areas of small power demand (e.g., Galena Alaska)
  - Considered a candidate for GNEP grid-appropriate small and medium reactor design
- Main features
  - Passive safety
  - No onsite refueling for 30 years
  - Low maintenance requirement
  - High inherent security



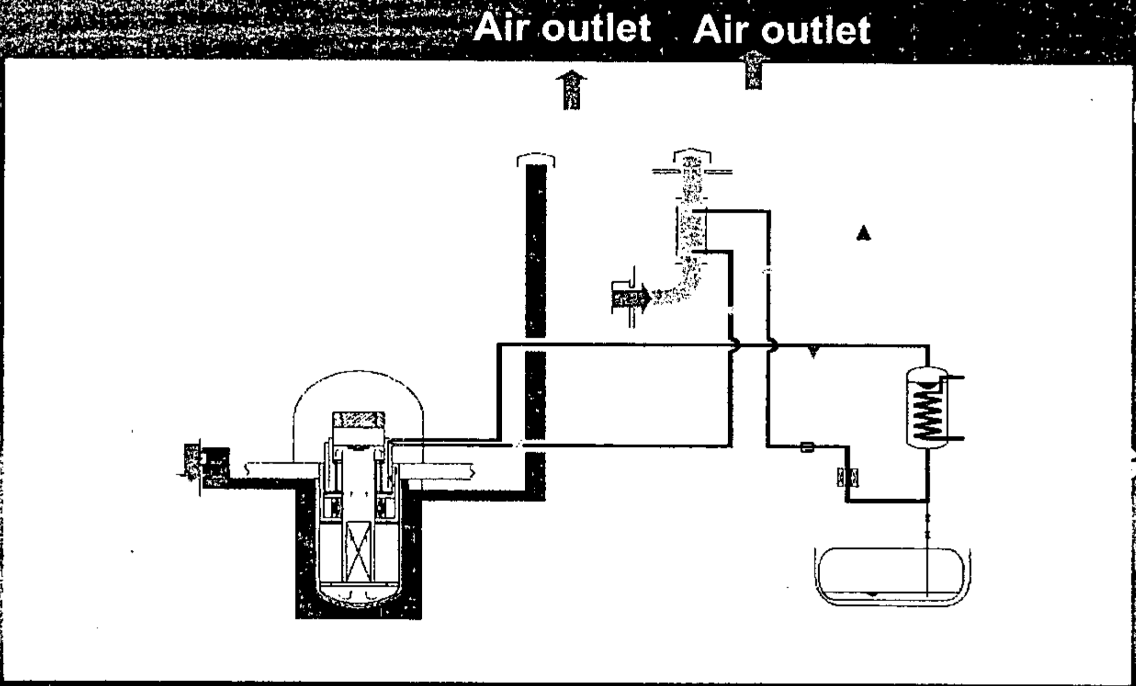
Plant Description

- Heat transport systems
  - Primary heat transport system: Inside the reactor
  - Intermediate heat transport system
    - Steam generator
    - EM pump
    - Air cooler
    - Dump tank
  - Water & steam system
    - Turbine Generator



Passive Decay Heat Removal

- **Heat removal by natural circulation & natural air draft**
  - RVACS: Natural air draft outside the guard vessel
    - Sufficient cooling capacity by only RVACS
  - IRACS: Natural circulation of sodium and air draft of air cooler



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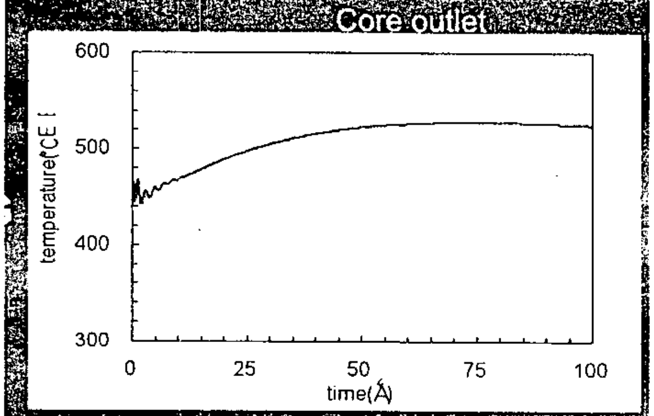
RVACS

Air flow pass

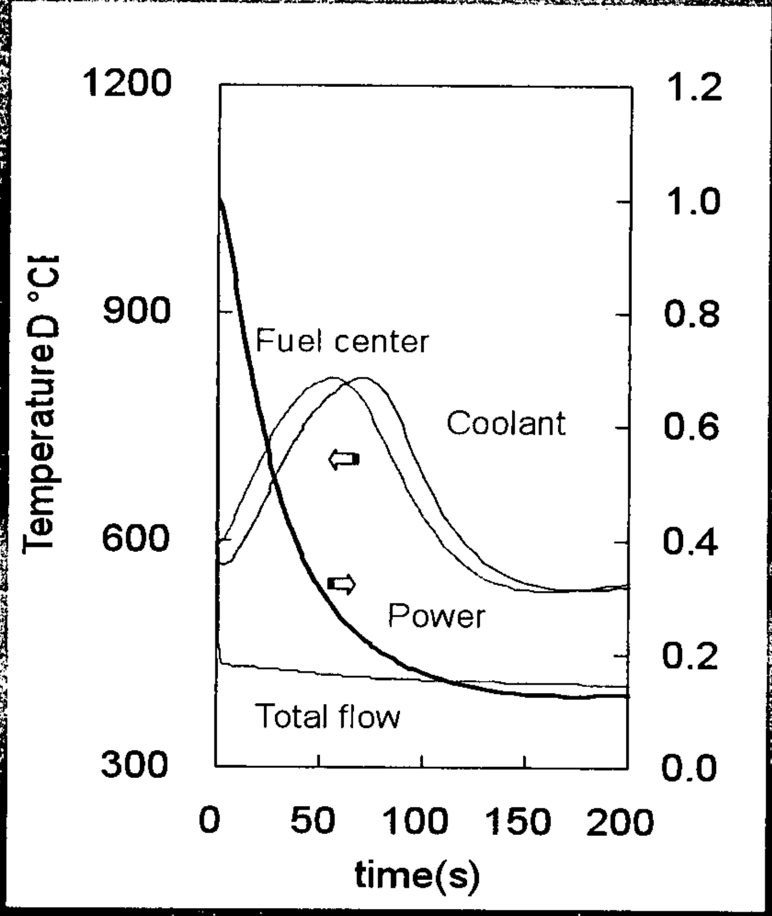


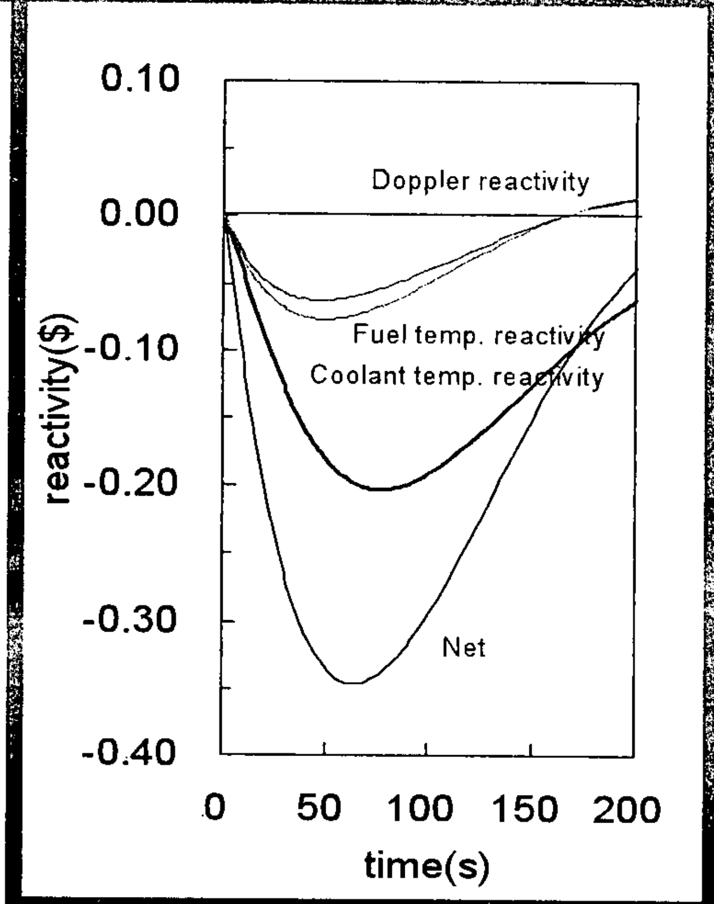
Loss of offsite power

Assumption : Heat removal by only RVACS

Passive Shutdown for Unprotected Events

- Safety Analysis of Unprotected sudden loss of flow
- Large margin to coolant boiling and fuel melting





Main Design Features

- Key Features of 4S
  - Passive safety
  - No onsite refueling for 30 years
  - Low maintenance requirement
  - High inherent security

Safety Features

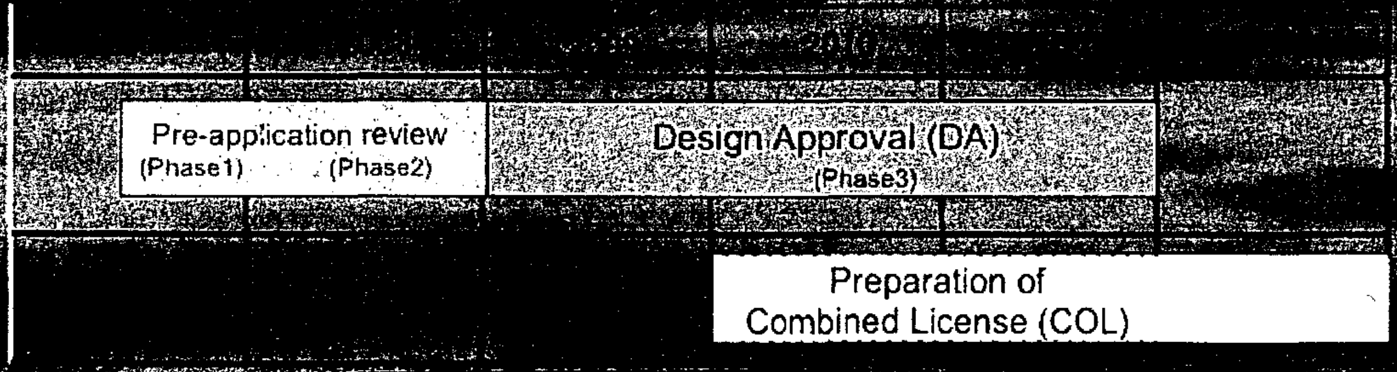
- [illegible] vessel
- Negative coolant temperature coefficient promotes safe, stable operation.
- Large margin to coolant boiling or cladding failure
- Reliable, redundant and diverse scram systems
- Smaller excess reactivity with metallic fuel core design – limited potential for reactivity insertion accident
- Passive, reliable, and diverse shutdown heat removal systems

Tests to Support 4S Design

Design Feature	Verification Item	Required Testing	Status
Long cylindrical core with small diameter Reflector controlled core	Nuclear design method of reflector control core with metallic fuel	Critical experiment	Done
High volume fraction metallic fuel core	Confirmation of pressure drop in fuel subassembly	Fuel hydraulic test	Done
Reflector	Reflector drive mechanism with fine movement	Test of reflector drive mechanism	Done
RVACS	Heat transfer characteristic between vessel and air	Heat transfer test of RVACS	Done
EM pump	Structural integrity Stable characteristics	Sodium test of EM pump	Done and Planned
Steam generator (Double wall tubes)	Structural integrity Heat transfer characteristic Leak detection	Sodium test of steam generator Leak detection test	Done and Planned
Seismic isolation	Applicability to nuclear plant	Test of seismic isolator	Done

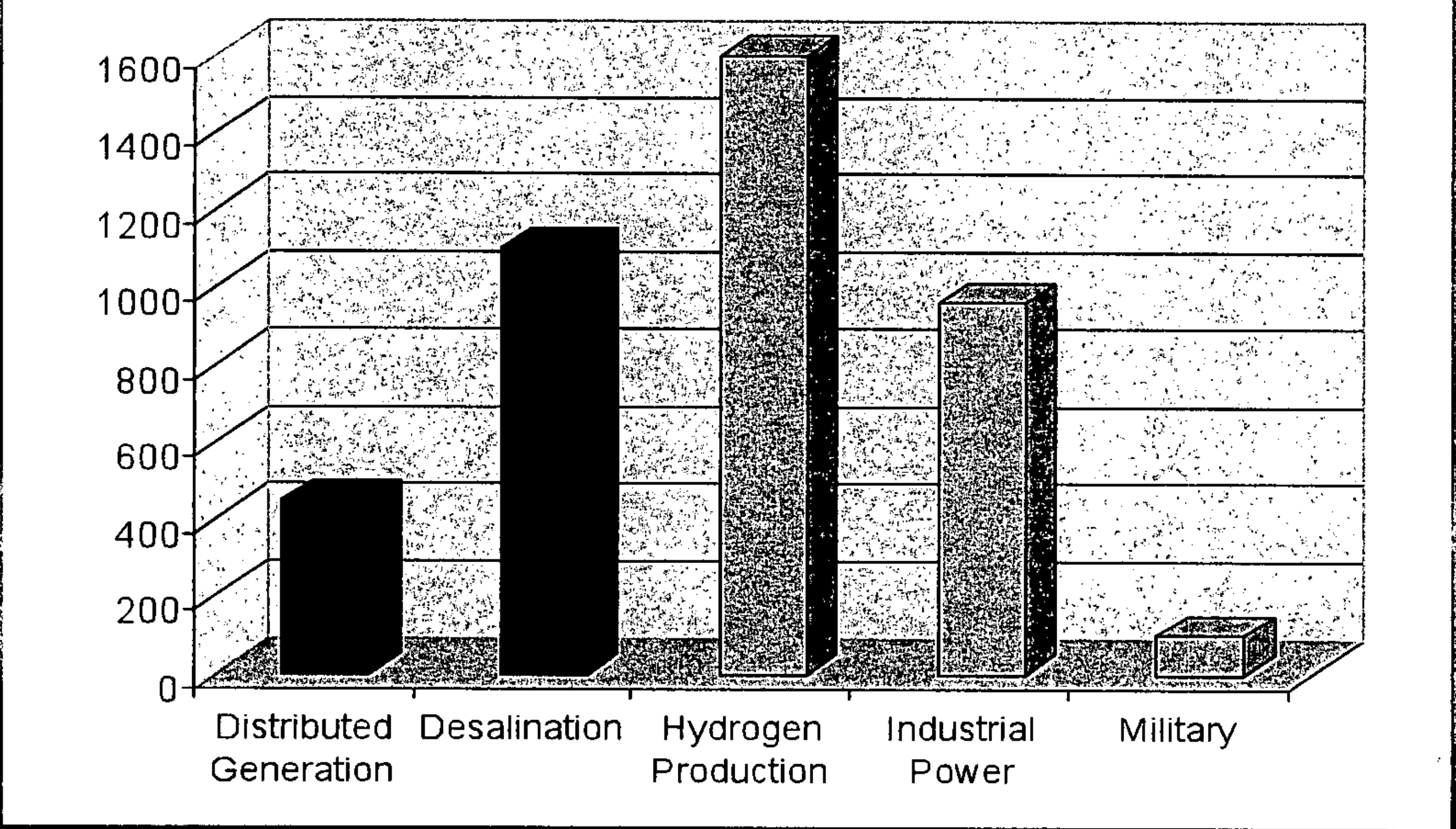
Proposed Licensing Approach

- **Submit Design Approval application in 2009**
  - **Phase 1:** Complete a series meetings with NRC to identify issues to be addressed before Design Approval application
  - **Phase 2:** Submit technical reports and obtain NRC feedbacks to address the issues identified in phase 1
  - **Phase 3:** Submit Design Approval application and obtain FSER
- **Application referencing Design Approval application Toshiba expects U.S. customer will submit a COL**



Small Reactor Market Niche Program Plan

Solutions LLC



Sample Commodity Costs – 10 Megawatts of Electricity Equivalent

M:T Solutions LLC

Commodity	Production Rate	10 MWe Yields:	Comments
Electricity	10 MW	240,000 KW/day	
Oxygen	567 scf/ min	817,071 scf/day	Assume electrolysis process using Teledyne Titan HP generator
Hydrogen	1134 scf/ min	1,634,143 scf/day	Assumes electrolysis process using Teledyne Titan HP generator
Desalinated Water	6,381 gpm	9,188,522 gpd	Assumes Salt Water Reverse Osmosis process with 35,000 ppm TDS input and producing 350 ppm TDS output

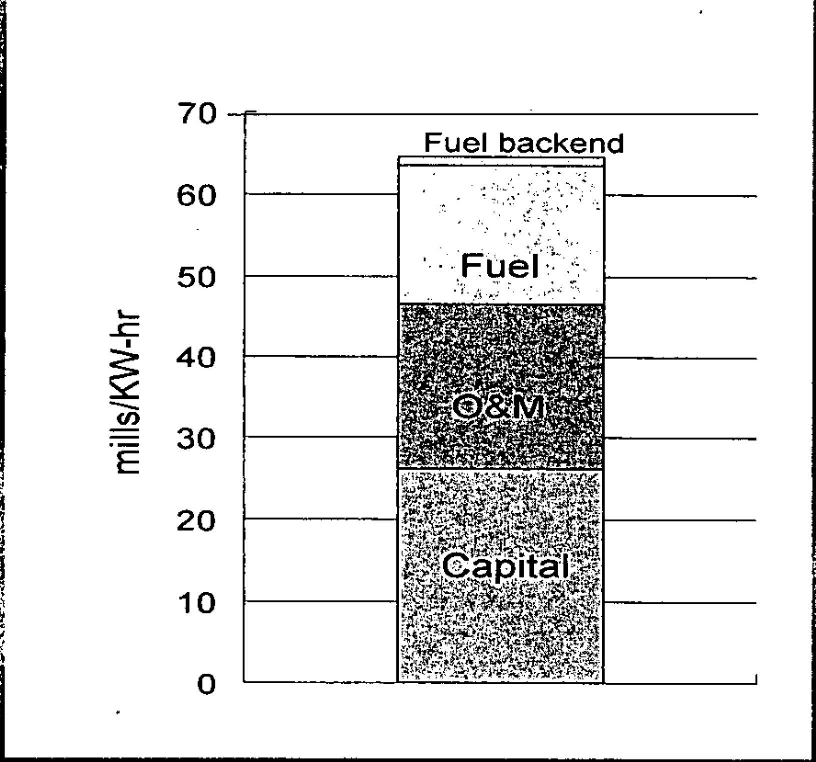
Galena Electric Power
–a Situational Analysis

M :T Solutions LLC

Nuclear: Possible Uses of Extra Power

- Hydrogen Production
- Greenhouses
- Aquaculture
- Galena as a test-bed
- Transmission to Neighboring Villages
- Increased use by consumers
- District Heat

4S Preliminary Cost Estimate



- 50MWe (135MWt) :
  10 MWE variant
- Commercial plant
  (mass production phase)
- Plant Construction:
  $ 2,500 $3,000/KWe

Busbar Cost:
$.065 mills-$.070 /KW-hr

M :T Solutions LLC

GNEP

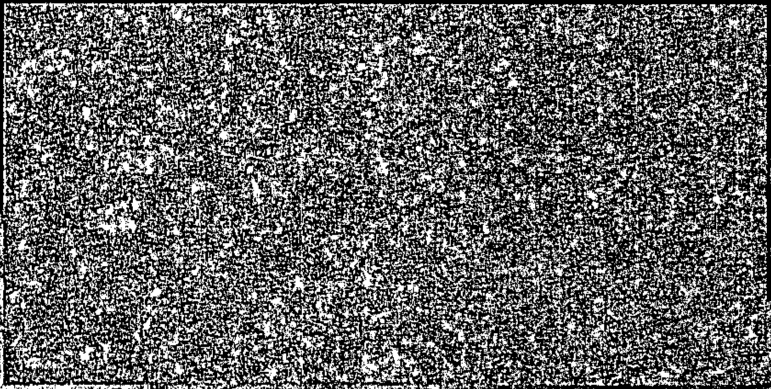
The Global Nuclear Energy Partnership

Greater Energy Security in a Cleaner, Safer World

President George Bush

GNEP Reprocessing

- Spent fuel rods



GNEP Element Demonstrate
Small Scale Reactors

- In order to expand the use of nuclear energy in these small electricity markets, a small reactor is preferred for small electricity grids. These reactors will be safe, simple to operate, more proliferation-resistant, and highly secure.

How the reactors would work

Small, more proliferation-resistant reactors could incorporate features that would ... include fuel designs that offer very long-life fuel loads (that last the entire life of the reactor); effective... safeguards ... to promote non-proliferation; potential for district heating and potable water production; fully passive safety systems; simple operation that requires minimal in-country nuclear infrastructure; use of as much existing licensed or certified technology as possible; and use of advanced manufacturing techniques.

Mohamed ElBaradei

M :T
Solutions
LLC

One potential strategy is to construct hundreds of mini-nuclear power plants that would each serve a single village, said ElBaradei. These plants would be less expensive than their full-size counterparts and could be set up without a need for an extensive power grid. In addition, the small-scale plants could be made with sufficient safety features to prevent meltdown and theft. This includes a passive cooling system that works even if power is shut down, said researchers this summer at Argonne National Laboratory. The reactors could also run for 30 years without the need to refuel, and any theft would require the use of large and conspicuous gear that could be visible by satellite, according to Argonne's senor technical advisor David Wade.

Nobel laureate Mohamed ElBaradei, director general of the International Atomic Energy Agency, gave this year's David J. Rose Lecture on "Nuclear Technology in a Changing World: Have We Reached a Turning Point?" Photo / Donna Coveney

Why Nuclear??

Remember the 1970's??

- Long gas lines
- High Gas prices
- Emphasize Alternative energy
- Domestic vs Oil Imports
- Global Cooling

Where Will the Hydrogen Come From?

M[illegible]:T
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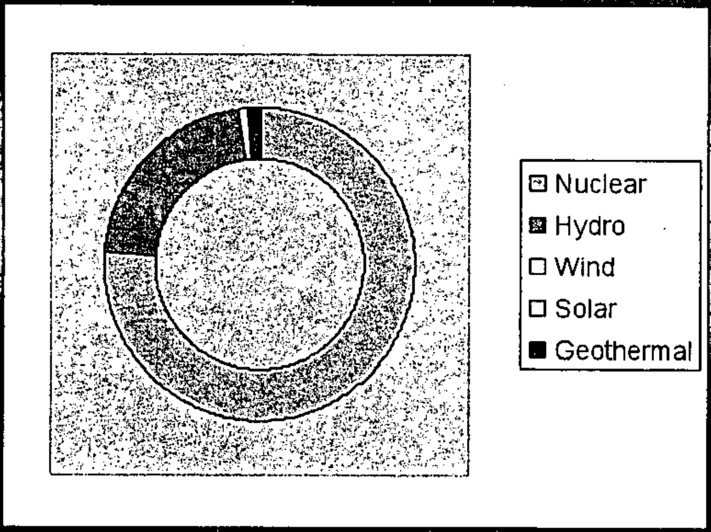
LLC

	Natural Gas	Nuclear	Solar	Wind	Biomass	Coal
Facilities	777,000	2,000 x 600mgw	113 mil x 40kw	1 mil x 2mgw	1.5 bil tons	1 bil tons
Cost	$l Trillion	$840 Billion	$22 Trillion	$3 Trillion	$565 Billion	$500 Billion
CO2 Emissions	300 Million tons	0	0	0	500 million tons	500 million tons
Cost per Gal						
Gasoline Equivalent	$3.00	$2.50	$9.50	$3.00	$1.90	$1.00

Emission Free Energy in the United States

Nuclear	Hydro	Wind	Solar	Geothermal
76.20%	21.60%	0.70%	0.10%	1.40%



Vision for the future

- The natural gas pipeline,
- Geothermal development at Mt Spurr,
- Hydroelectric projects,
- Wind projects,
- Nuclear power
- Coal to liquid project

Conclusions

- Nuclear Power -50 years without a fatality
- Secure 19% enrichment -non weapons grade
- Burner Reactor -uses reprocessed fuel
- Auto shut down -no operator error

Toshiba 4S Project

- Thank you

Marvin Yoder

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Many are licensed but few are built

We built nearly 100 plants in the 50's and sixties until a combination of the reduction in electricity demand, public protest, and regulatory overkill in the 1970's made further building of power reactors too uncertain and expensive. Now over 30 years later we have not completely overcome this lost momentum and actually started building plants again.

The regulatory environment is now more predictable (but way too slow), demand is up, and as people have gotten more familiar with nuclear power their earlier fears have dissipated. Now over 60% of our population wants to expand the use of nuclear power (and virtually all of the technically competent). Of course we still have some techno-phobics and can expect lawsuits attempting to derail almost any energy project. However, nuclear has proven to be the safest, and most healthy heat source for generating significant electrical power.

The licensing process is very slow, but the NRC has set up a regime in which, once construction has started, challenges to prevent operation should be very difficult. The process now consists of a two licenses. The first certifies the design of a type of plant. Four plant designs have been certified and 4 more are under review. A number of others are in a pre-review phase. As long as a builder picks a certified design that portion of the project is exempt from further review except to insure the design is carried out. The second license is the Combined License (COL) which is specific to a site and covers the builder's qualifications, environmental impacts, operation, site safety, design safety, and construction verification. As of March 9, 2009 the NRC has received COL applications for 26 plants at 17 sites. At least 13 of these sites already have operating nuclear plants, so the new reactors represent an expansion.

How many of these new plants will be built is open to question. Since the NRC process takes years, the operators must anticipate future power requirements at least half a dozen years in advance. Current economic conditions might well suppress demand for some years. The effect of a new a administration is also unknown. President Obama has said he favors nuclear power, but his actions seldom correspond to his words. We will have to see.

Meanwhile current developments in small nuclear power plants suggest that small factory produced reactors may be a way to compress the approximately 4 year build time (regulatory matters take many additional years) for a large reactor.

Meanwhile, there are 104 operating power reactors in the United States producing nearly 20% of our power. The utilities operating these reactors are carrying bundles of cash to the bank because their fuel costs are so low and their capital costs have been recovered.

Short, medium and "permanent" storage of nuclear waste

The difference between short term (5-30 years), & medium term (10-500 years) storage of nuclear waste; and permanent storage has become politically huge. I have written a paper on the very long term storage of high level waste which is attached.

The cost of short term and medium term storage is very manageable, but predicting the cost of storage for some forms of very long term storage is more difficult. I would assert that the remaining problems are primarily political and driven by lack of information dissemination. The government has been collecting fees from all U.S. nuclear power generators to provide this long term storage, but so far they have missed every deadline, and Obama just back-burnered the facility that was expected to take the long term storage. Meanwhile most plants have adjusted and can keep the waste on-site for a few hundred years after which it is much safer to handle.

One of the differences between nuclear waste and ordinary chemical waste is that nuclear waste steadily degrades to safer end products and does this on a predictable and very reliable schedule. Unfortunately for some parts of the waste this is a very long time. Chemical waste on the other hand is essentially eternal in the absence of a chemical reaction to change it to a safer material. Compared to the waste from a coal plant the waste from a nuclear plant is also very tiny.

President Carter committed the U.S. to a once through fuel cycle which uses about 3% of the slightly enriched uranium placed in the reactor's fuel rods. He had some reasons, but they were questionable at the time, and have become even less relevant as the years have passed. I'll be glad to describe this at length at our next lunch.

Reprocessing the fuel reduces the waste dramatically and also permits the plutonium (with a very long half-life) to be "burned" as reactor fuel. This in brief is why some of us did not want to see the (slightly) used fuel being "permanently" stored.

Nuclear power in Alaska

Alaska has a different set of power requirements than the other states. The scale of our power is much smaller and in fact electricity for the entire state could be generated by one plant of the type the NRC has certified so far. Of course there would be no reasonable way to transmit the power to the locations where it is needed.

At the same time, nuclear and hydro power offer the only consistent, reliable, significant scale generation capability that will free Bush centers from their reliance on fuel oil generation. Wind can contribute a bit in some communities but is not reliable or cost effective. Wind is usual grouped with solar and geothermal and described in the industry as "piddle" power. I've enclosed an Excel spreadsheet showing the 2007 percentages of power produced using the various fuels.

Planned for Galena is a 10 MWe Toshiba 4S. This is less than 1% of the size of reactors the NRC has certified. They have had a series of pre-certification meetings and a formal certification application may be submitted this year. If all goes well, it would be possible to have a 4S in Galena in 2015.

A number of other communities around the state should consider these. I have written a letter to the Governor to suggest a few things the state could do that would have vast long term benefits for regional Bush locations. I have enclosed a copy.

In brief, these include helping suppliers and communities deal with federal regulatory issues, helping with technical evaluations, and getting federal security measures adjusted for small and underground reactors.

Nuclear Power in Anchorage

Anchorage has a number of good choices for additional power generation (Wind is a poor choice). The initial implementation may be more natural gas since the area has additional power requirements in a shorter time frame than nuclear or hydro power can be brought on-line. This is indeed unfortunate as it will drive electric rates to high levels and draw on the heating supply for gas that is better used in that venue.

I prepared a report for the Chugach Electric board (attached) and Marvin Yoder and I gave reports to the board. They are currently playing catch-up for past years of weak forward planning. They see a wider variety of fuel sources in their future.

One idea currently being discussed is to order a Toshiba 4S (possibly in the 50 MWe configuration) as a test demonstration of it's viability for the Bush and as an incremental power source for the railbelt.

Alaska State Law

A few sentences in Alaska state law could also slow or stop our progress toward more consistently affordable electricity. Representative Craig Johnson is working up a draft bill to submit (Jeanne Ostnes is currently collecting comments). The draft from the 12th is attached. I hope you can co-sponsor this legislation and push it through.

Good luck with the final push of this session!

Cheers,
Don

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PS: I will also sent copies (with notes) to Sarah Palin's office, Johnny Ellis, and the Alaska Energy Authority.

High level nuclear waste

(2,090 words)

Donald N. Anderson
http://don.softwarenorth.net/NuclearElectricty.html
Anchorage, Alaska
30 January 2008

When discussing nuclear power in 2008 I am often asked "What about the waste?" The following would be my answer if the niceties of conversation permitted something beyond bumper sticker platitudes. When questioners wanted more detail, I would refer them to the two books mentioned in the footnotes.

Production of electricity using nuclear fission leaves as a troublesome byproduct -- a small amount of highly radioactive waste[1]. Most of this dangerous waste is embedded in fuel rods removed from the reactor core after they reach the end of their productive life. In most of the U.S. light-water reactors these fuel rods start out with about:

- 96% uranium-238, non-fissionable
- 4% uranium-235, fissionable[2]

What's in the radioactive waste?

The radioactive waste consists of a large number of elements and different isotopes. Some waste is formed by splitting uranium-235 or plutonium-239 into smaller elements, often their less stable isotopes. Other waste is formed by neutron bombardment of the uranium-238 that comprises most of the fuel content. Spent fuel rods contains about:

- 95% uranium-238,
- 1 % uranium-235, and
- 1 % plutonium-(mixed isotopes).

The rest is primarily a mixed fission product with some actinides (transuranic elements -- elements heavier than uranium). Most of the material in spent fuel is not waste at all, as we shall discuss below.

Reprocessing?

Spent fuel rods contain much of the original fuel, but the uranium-235 has become too dilute to sustain a fission reaction. They can, however, be reprocessed to recover uranium and plutonium to fabricate new fuel elements. France and many other countries have reprocessed spent fuel for decades, even though it requires working with highly radioactive materials and is quite expensive.

The U.S. stopped reprocessing over 3 decades ago -- a political decision that grew out of the Carter-Ford presidential campaign, and has a once-through fuel cycle. This means our "waste" not only includes the small amount of really nasty products, but also much fuel

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[1] I am indebted to Scott W. Heaberlin for his detailed and cogent description of reactor waste in chapter 6 of his 2004 book "A Case for Nuclear-Generated Electricity."

[2] I hope technical readers will excuse me if I bypass a lot of complicating detail and variations in fuel load so I can focus on the essentials of storing nuclear waste.

that could be reused. The volume of high-level nuclear waste is extremely small compared to the waste generated by a coal plant, but could be made significantly smaller if reprocessing is resumed and carried as far as economically feasible[3]. The amount of really deadly waste generated while supplying a family with power for 20 years would approximately fill a shot glass (1.5 fl. oz.).

That deadly radiation.

Some fission waste products initially have very high levels of deadly radiation, but have short enough half lives, so that they convert to more stable isotopes in a relatively short time. For example, iodine 131 has a half life of 8 days. Therefore after 2 months only half of 1 percent remains. If fuel rods are to be reprocessed, they are easier to work with if a few years have elapsed since removal from the reactor.

The most troublesome fission products are those with half lives of intermediate length. They emit enough radiation to be dangerous over a much longer period (cesium 137 has a half life of 30 years). They are not, however, going to be around "forever," as will chemical poisons such as mercury or lead.

Short term storage.

Fuel rods are usually changed about every 18 months in a light-water reactor (the majority of the U.S. fleet). One third of the fuel rods are replaced with new fuel rods on each occasion. Thus each fuel rod spends about 4 and a half years in the reactor. One minute after a reactor is shut down its fuel produces 2.5% of its full operating heat. After an hour its fuel produces 1%, after a day 0.5%, and after a year only 0.05%.

Over the first few years, the residual heat from the spent fuel rods is dissipated by placing them in large pools of water. The intent is to move the waste fuel rods to long term dry storage after a few years.

Originally the U.S. government planned to open a long term repository for reactor waste at Yucca Mountain in Nevada. It has collected 20 billion dollars from the nuclear industry, but so far has missed all milestones. Worse, the project has now received a great deal of Nevada political opposition.

Meanwhile the 104 nuclear reactors that produce 20% of our electricity continue to store spent fuel rods on their plant sites. After the high initial heat has bled away many plants have opted for intermediate storage in stainless-steel concrete casks. These casks could store the waste for several hundred years, and longer if necessary.

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[3] Dr. Phillip J. Finck of Argonne National Laboratory, in testimony before the Energy Subcommittee of the House Committee on Science, 16 June 2005 has an excellent description of the ongoing research into what is called Full Recycle. This has the promise of reducing the dangerous waste still further and virtually eliminating the dangerous transuranics.
http://www.anl.gov/Media_Center/News/2005/testimony050616.html

Seabed storage.

In 1973 Rip Anderson from Sandia Labs and Charles Hollister from Woods Hole Oceanographic Institution put together a team of oceanographic scientists to study deep seabed storage of high-level nuclear waste[4]. Eventually the team grew to 200 members with almost every discipline represented. Most biology team members were selected because they initially opposed the concept and would insure it was properly tested.

Hollister developed a technique for getting long cores from the deep seabed, and found a number of areas in the deep ocean that can only be described as deserts. One of these is at 35N164W about 600 miles north of Hawaii. It is situated in the middle of a tectonic plate under 4 miles of ocean and covers approximately 39 thousand square miles. The ocean floor in that area is a thick blanket of viscous clay about 325 feet deep. No marine life is present – no fish or plants. Currents are feeble and the area has been undisturbed by volcanic or seismic activity for 35 million years.

The clay is a quicksand type material that quickly absorbs any dense material dropping into the area. Thus, any injected waste canisters would be absorbed deeply in the clay. It is ideal for sequestering radioactive products. In spite of this the biologists spent ten years studying what would happen if the radionuclides actually escaped.

After all the research and a high quality risk assessment, the team concluded that seabed disposal was the best possible option and a couple orders of magnitude better than the most widely discussed alternative. Since most of the assessment had been made using retrieved data and models, the scientists proposed a final check. They suggested dropping a couple of pointed steel test canisters into mud at 35N164W to a depth of 100 feet. A twenty year monitoring of the canisters was proposed to calibrate their models.

Politics rather than science ruled, and Congress passed a bill in 1987 that designated Yucca Mountain in Nevada as the nation's long term repository for high level waste. Funding for the seabed storage project was terminated and the final check left undone.

Retrieval of waste fuel for potential reprocessing is not currently feasible from such deep ocean sites.

Yucca Mountain.

Yucca Mountain is located in a geological basin in a remote part of the government's Nevada test site which has been subjected to over 900 nuclear bomb tests. It has been studied intently, has reams of data describing it, and is very dry.

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[4] Gwyneth Cravens in chapters 16, 17, and 18 of her 2007 book, "Power to Save the World" contains an exceptionally well written description of the seabed studies, the Yucca Mountain repository, and the Waste Isolation Pilot Plant (WIPP).

Unfortunately its geology is quite complex. When one stacked all the researcher's "it couldn't be worse than this" assessments for the next 10,000 years together it sounded as if under some circumstances radiation could escape.

Opponents pounced on every imagined weakness. They even got the State of Nevada to oppose the project. A Las Vegas newspaper had visions of delivery trucks overturning or terrorists attacking them on the highways.

The facility has been built, but never used. Court challenges and a requirement for a licensing report to the NRC have held up its opening. The long, tedious process of doing a high quality risk assessment (as was done for the Seabed Project and the Waste Isolation Pilot Plant) with each data point fully pedigreed is underway. The NRC expects to take 5 years to review the result.

Unless Congress changes the rules it appears operation of Yucca Mountain is still some years off.

Meanwhile it may be instructive to look at the experience we have had with the only long term nuclear waste facility in the world that is now open and fully operational.

Waste Isolation Pilot Plant.

The Waste Isolation Pilot Plant (WIPP) located in the Chihuahuan Desert about 20 miles east of Carlsbad, New Mexico is operated by the Department of Energy. WIPP is not currently licensed to handle power plant waste fuel or any waste generating significant internal heat, although research indicates it could do so.

The storage bays and tunnels are 2,150 feet underground in a 2,000 foot thick salt bed that has been stable for over 200 million years.

The storage facility is designed to permanently isolate both contact-handled and remotely-handled transuranics that have been produced in the nation's nuclear bomb program or in research reactors. Contact-handled waste can be safely moved as long as it is in drums and usually consists of clothing and chemicals that have become contaminated by exposure to significant radiation. The remotely-handled materials require those who move it to be shielded.

This military and research waste came from many locations across the U.S. although by 1999 much had been consolidated at the Idaho National Laboratory in eastern Idaho. The portion currently being transported to WIPP was produced as far back as WWII. Interim storage was in drums and shallow graves in isolated sites.

Planning started in 1974 and operation commenced in 1999 with the first shipments of contact-handled waste. By 2006 over 5 thousand shipments had been received. In 2007 the first shipments of remotely-handled waste were received.

Unlike Yucca Mountain, WIPP has the support of local groups and the state of New Mexico. It also benefited from a thorough high-quality risk assessment with open data and computer codes that eventually brought many possible opponents aboard. The much simpler geology also made the risk assessment much easier.

To ease transport fears the special trucks were equipped with casks and demonstrated in towns along the New Mexico routes.

Could WIPP store high-level commercial power waste? Yes. In spite of claims to the contrary, waste with higher heat content can be stored in the salt. The salt bed is so vast that an extremely large number of storage chambers can be excavated. With reasonable spacing salt conducts heat well enough to accept waste commercial reactor fuel.

To date public fears have prevented the inclusion of high-level commercial power waste. Most of the scientists involved think that as more people observe years of safe operation of the transport and storage at WIPP, fears will dissipate.

Political not technical problems.

Years of exposure to public fears, agonizing court battles, and educating judges in subjects outside their normal areas of expertise have made the nuclear industry extremely safety conscious. This extreme safety orientation, the low fuel cost, plus the small quantities of waste have permitted extraordinary expenditures in the name of safety. Coal power generation simply could not afford a similar attention to waste. Safety procedures that would be rejected as not cost effective by other industries are routinely adopted by the nuclear industry.

This extreme attention to public safety has caused very expensive cleanups. Often the cleaned area becomes less radioactive than its natural surroundings. It has also led to a power generation industry that has a safety track record far better that <u>any</u> alternative.

Radiation levels permitted at a plant's fence are far lower than the natural radiation levels we are exposed to every day. The actual radiation level from an average coal fired plant is about 30 times <u>more</u> than the allowed level from an equivalent nuclear-fueled plant. In addition the coal plant has many other dangerous emissions that are not produced by a nuclear plant.

As with any "new" technology there are many who fear it. But the nuclear industry has gone to extreme lengths to minimize any safety concerns. There is hope that the public will finally allow the nuclear industry's expansion and the gradual opening of suitable long term storage for waste.

Knowledge increases most people's comfort with new technology. By 2007 about 60% of Americans favored expansion of nuclear power. In contrast by 1980 the much more knowledgeable scientists, even after the Three Mile Island incident, were already much more strongly in favor of expanding nuclear power[5]:

• all scientists	89%
• energy scientists	98%
• nuclear scientists	100%

Public perception, the fear of the unknown and the resulting political obstacles have impeded long term storage of high-level waste. The technical problems that remain are site specific and several alternatives exist.

The principal problem that remains is political.

Dr. Anderson is an Anchorage, Alaska businessman and physical chemist. He wishes to thanks Ed Johnson of Sunnyvale, California for his technical fact checking and editorial suggestions and Dana G. Anderson of Anchorage for her many formatting and readability suggestions. He claims ownership of any remaining errors.

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[5] Cravens, page 112.

January 29, 2009

Donald N Anderson, PhD
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RE: Small nuclear power generation reactors for Alaska cities.

Governor Palin,

AT PRESENT

I have studied the potential for Chugach Electric to use nuclear reactors to generate stream for their generators. The results were favorable, but involve a long timeline. Their board has the matter under consideration.

The town of Galena has been seeking licensing for a 10 MWe nuclear power reactor [4-S] to generate electricity and provide heat for their city for some time. The 4-S planned for Galena has a 30-year supply of fuel sealed in a volume about the size of 4.5 barrels of oil. It replaces over 500,000 barrels of oil. A 10 MWe reactor produces less than 1% of the power of the large 1,000 plus MWe reactors that are the new generation planned for the S.48. As such they are much smaller and require a great deal less attention.

IN THE FUTURE

I have started a very preliminary study to see what other Alaska cities might benefit from small reactors. The benefit to remote Alaskan communities is the fantastically smaller volume of fuel required.

I first considered cities that were off the railbelt power grid and were Galena's population or larger. I added a few smaller cities that were generating hubs for the their areas. I collected some 2001 Net Capacity figures from that year's ISER report[i] and noted the type of fuel used. This provided a potential list of 41 cities to be considered for small reactors.[ii]

Given the tremendous reduction in the fuel volumes needed, transportation costs and seasonal problems become very minor. It is easy to see that very substantial economies are possible, provided the remote site is able to use the amount of power generated. The current power reactor designs proposed for licensing are still a bit too large for most remote Alaska villages, but a number of regional centers could really benefit. The benefit is likely to be so substantial that in-migration from the surrounding countryside would undoubtedly increase.

In the table below I have selected those cities that appear to be possible initial candidates for a small reactor. Kodiak and Yakutat were added because their fuel oil consumption was quite high. Of course local interest must be the major driving force, but it appears these 13 locations might benefit.

Region	City of	Population[iii]	(MWe) Net Capacity[iv]	Type[v]
Aleutians	Unalaska	4,388	29.5	IC
Bering St	Unalakleet	741	4.1	IC
Bristol Bay	Dillingham	2,373	17.5	IC
	Naknek		20.1	IC
Interior	Tok		11.6	IC
Kodiak	Kodiak	6,138	41.6	IC, 91.9 HY
Kuskokwim	Bethel	5,899	41.2	IC
M Yukon	Galena	763	9.4	IC
NW Arctic	Kotzebue	3,076	20.9	IC
S Central	Copper Valley		16.6	IC, 50.8HY, 22.5GT
	Cordova	2,372	20.8	IC, 2.9 HY
Southeast	Yakutat	691		IC
Seward P	Nome	3,448	27.8	IC

THE ROLE OF STATE GOVERNMENT

The Alaska state government can play a big role in helping to start the implementation of this major improvement in access to electricity for non-railbelt cities specifically in the areas of licensing and security.

LICENSING

Nuclear power is generated in an intense regulatory environment in facilities that are capital intensive but use very low cost fuel. The Federal Nuclear Regulatory Commission is used to working with facilities that are 100 times larger than the 4-S proposed for Galena. Their extremely detailed control does not destroy a large reactor's cost effective generation of electricity. But it could be a "showstopper" for small reactors.

The NRC licenses a reactor design and also licenses each site through a COL (COmbined License) that guides the actual construction and operation. The detail in the COL needs to be lowered to a level that makes sense and makes these small reactors cost effective. The state could well take over this aspect.

If the state and our congressional delegation work together with the NRC to devise regulation, safety, and security standards appropriate to these small reactors they will provide a major step toward powering bush Alaska. At the very least, the state's assistance in obtaining the necessary licenses would place this expertise in one group rather than duplicating it across the state.

CURRENT POTENTIAL LICENSEES

At present it appears that 3 designs will be proposed to the Nuclear Regulatory Commission for the appropriate design license. Each produces steam for a generator. They are:

Toshiba/Westinghouse 4-S, 10 or 50 MWe.[vi]
30 year without refueling for 10MWe unit,
Sodium moderated and cooled,
No accessible parts. Unit replaced after 30 years,
Installed underground,
Has started the regulator approval process and will probably be the first to be licensed,
Size appropriate to some Alaska bush cities.

NuScale Power, a scalable 40 MWe unit.[vii]
Light water moderated and cooled,
Transportable by truck, barge or rail. 300 tons,
24 month, on-site refueling cycle.

Hyperion Power Module, 25 MWe unit.[viii]
Seven to 10 years without refueling,
Installed underground.

SECURITY ISSUES

The large amount of fuel and above-ground design of 1,000 MWe reactors [inappropriate for Alaska] generates fears of terrorist attack and nuclear proliferation. This leads to significant security expenditures.

The state could be of great service in getting these security expenditures reduced to a practical level for the small reactors, particularly since these reactors are designed to be installed well underground.

I believe providing technical and regulatory assistance to these rural communities in the acquisition of new power sources is the most important long-term benefit the state government can provide for bush Alaska.

I can be contacted via email don.anderson@softwarenorth.com or at the phone numbers provided below, and will be glad to provide your staff via regular email the Excel workbook on which this letter is based and additional information on nuclear power and waste disposal.

Best wishes,
Don

Donald N Anderson, PhD
Manager, Software North LLC
Anchorage, Alaska
907-561-4412 / 800-228-3846

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[i] ISER 2001 report of Alaska Electrical Generation, www.iser.uaa.alaska.edu/Publications/akelectricpowerfinal.pdf

[ii] A Excel workbook containing the list of Alaska cities with associated populations, electrical capacity, fuel usage and type is available on request from: don.anderson@softwarenorth.com

[iii] 2005 Municipal Officials Directory.

[iv] ISER 2001 report of Alaska Electrical Generation

[v] IC = Internal Combustion (fuel oil), HY = Hydroelectric, and GT = Gas Turbine.

[vi] A description of the proposed Galena installation is at http://www.alaskajournal.com/stories/122604/loc_20041226003.shtml

[vii] http://www.nuscalepower.com/

[viii] http://www.hyperionpowergeneration.com/

Summary Statistics for the United Statés 2007

Net Electrical Generation

Energy Information Administration

http://www.eia.doe.gov/cneaf/electricity/epa/epates.html

Report Released: January 21, 2009

Table ES1. Summary Statistics for the United States [2007 extract]

	Fuel	Thousand megawatthours	Percent
1	Coal[1]	2,016,456	48.51%
2	Natural Gas	896,590	21.57%
3	Nuclear	806,425	19.40%
4	Hydroelectric Conventional[4]	247,510	5.95%
5	Other Renewables[5]	105,238	2.53%
6	Petroleum[2]	65,739	1.58%
7	Other Gases[3]	13,453	0.32%
8	Other[9]	12,231	0.29%
9	Pumped Storage[8]	-6,896	-0.17%
	All Sources	4,156,746	100.00%
Other Renewables			
1	Wood and Wood Derived Fuels[6]	39,014	0.94%
2	Wind	34,450	0.83%
3	Other Biomass[7]	16,525	0.40%
4	Geothermal	14,637	0.35%
5	Solar Thermal and Photovoltaic	612	0.01%

[1] Includes anthracite, bituminous, subbituminous, lignite coal, waste and synthetic coal.

[2] Distillate fuel oil (all diesel and No. 1, No. 2, and No. 4 fuel oils), residual fuel oil (No. 5 and No. 6 fuel oils and bunker C fuel oil), jet fuel, kerosene, petroleum coke (converted to liquid petroleum, see Technical Notes for conversion methodology) and waste oil.

[3] Blast furnace gas, propane gas, and other manufactured and waste gases derived from fossil fuels.

[4] Conventional hydroelectric power excluding pumped storage facilities.

[5] Other renewables represents the summation of the sub-categories of Wind, Solar Thermal and Photovoltaic, Wood and Wood Derived Fuels, Geothermal, and Other Biomass.

[6] Wood/wood waste solids (including paper pellets, railroad ties, utility poles, wood chips, bark, and wood waste solids), wood waste liquids (red liquor, sludge wood, spent sulfite liquor, and other wood-based

[7] Biogenic municipal solid waste, landfill gas, sludge waste, agricultural byproducts, other biomass solids, other biomass liquids, and other biomass gases (including digester gases, methane, and other biomass

[8] The generation from a hydroelectric pumped storage facility is the net value of production minus the energy used for pumping.

[9] Non-biogenic municipal solid waste, batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, tire-derived fuels and miscellaneous technologies.

Should Anchorage generate electricity with nuclear power?

Donald N. Anderson – http://don.softwarenorth.net
Anchorage, Alaska — 27 February 2008 – (7,075 words)

This essay provides background for the directors of Alaska's largest electric utility and for those who wish to understand the tremendous superiority of nuclear power for electric power generation.

Sections:

- The 30-year shutdown in U.S. nuclear power plant construction
- The impact of nuclear fearmongers
- How does nuclear power work?
- Features of a nuclear power station
- Cost comparison
- Comparing fuels for generating electricity
- Safety & health while generating electricity
- Alaska's chance for nuclear power
- Glossary

Anchorage should consider generation of a substantial portion of its electric power using a nuclear reactor as the heat source.

The 30-year shutdown in U.S. nuclear power construction

Building nuclear-fueled power plants began with great promise in the 1950's. Some of you will remember the hype of the 1950's when the low fuel costs of nuclear power made some speculate that it would be too cheap to bother metering. By 1980 no new reactor construction was being started in the United States. Only a few much delayed plants were completed after that point.

The public attitude began to change in the late 60's as the newly sensitized environmental movement started lashing out in all directions. Nuclear power was an ideal target because:

- It was new
- Public experience with it was very limited
- People had only a short track record to use in evaluating the enviros' wild claims
- It also was mysterious
- It was connected to those horrendous bombs
- It invisibly could cause cancer and death

In reality more was known about the safety and health effects of nuclear power than any of the more traditional forms of electricity generation. Unfortunately specialists who had this knowledge were quickly marginalized as self-interested participants in the industry.

Even today the health of nuclear power workers and any exposed members of the general public are intensely studied.

Comparable studies into the health effects of coal generation are not nearly so comprehensive, but do show that coal is many orders of magnitude more dangerous to both workers and the general public.

The impact of nuclear fearmongers

In the late 60's and 70's those fearful of the new technology such as Helen Caldicott, and Ralph Nader used the public's ignorance of nuclear physics to sell the idea that nuclear power generation was unreasonably dangerous. These ideas persist into the current era.

Representative of the misinformation used to discourage construction of nuclear plants were:

"Plutonium 239, one of the most dangerous elements known to humans, is so toxic that one-millionth of a gram is carcinogenic." – Helen Caldicott.

Plutonium-239 has about the same toxicity as lead. It is, however, a slightly radioactive alpha emitter and, if inhaled, can damage some cells (see *Radioactive* in

Glossary) and increase the potential for future cancer. A former U.S Senator from Alaska once claimed that Plutonium was the most toxic substance known to man. I hope he has since become better informed.

"[A nuclear accident would result in] up to 100,000 deaths and the destruction of an area the size of Pennsylvania" – Ralph Nader.

Mr. Nader does not specify the type of accident he is postulating. Even a nuclear explosion (impossible for a power reactor) would not damage a major part of Pennsylvania. One would have to violate the physical laws of the universe to get a nuclear explosion using the fuel in a power plant. Anyone with even a little knowledge of the subject wonders what Nader was smoking.

"When things went awry at the Enrico Fermi reactor near Detroit, four million people went about their business in happy ignorance, while technicians tinkered with the renegade's invisible interior. They knew what the public did not – a mistake could trigger a nuclear explosion." – M.E. Gale.

The Fermi 1 plant lost coolant to 2 of its 100 fuel assembles and some fuel melted. The safety systems all worked and the plant was repaired and resumed operation. There was no danger to Detroit (or even the plant operators). No nuclear explosion was possible.

"By the end of the decade our rivers may have reached the boiling point: three decades more, and they may evaporate... One of the causes of this thermal pollution is the spread of nuclear power across the land." – Edwin Newman.

Nuclear plants produce the same amount of waste heat as a fossil fueled plant of the same size and efficiency.

There is no end to the number of inflammatory statements because they can be made up on the spur of the moment and backed with manufactured statistics. Proper replies often require significant research so keeping up is not possible. The above examples were given so you could sample the flavor.

These statements raise fears and very pointedly ignore accurate information that might destroy their emotional potential.

The nuclear fearmongers of both present and past describe any information or research that contradicts their assertions as lies. They succeeded in sowing distrust of anyone with the technical knowledge able to expose <u>their</u> lies.

Spreading fear is a great way to gain notoriety and make money, but does not lead to good public policy.

Unfortunately for public health, fear of the unknown stopped further deployment of nuclear power in the United States for over 30 years. The U.S. -- initiator, developer and onetime technology leader -- is stalled at 104 commercial plants.

Some other nations have had similar opposition to nuclear power. Austria, Australia, Italy, and New Zealand are officially nuclear-free zones and a few countries have committed to closing their nuclear plants. Most are reconsidering.

Meanwhile, deployment worldwide has continued and there are now 334 operating plants in other countries. Nuclear plant operating experience (worldwide) totaled a cumulative 12,000 reactor-years by the end of 2005. The U.S. Navy has run 254 plants (up to 190MWt) accumulating over 5400 reactor-years of experience with no accidents.

U.S. construction was stopped by a combination of:

- lawsuits
- delaying injunctions
- over-regulation
- protests
- high interest rates,
- Three Mile Island

Regulators, under pressure from those fearful of the new technology, forced changes to plant design while construction was underway. Construction costs went through the roof. The delays generated cost over-runs that bankrupted some utilities and ran capital costs up so high that nuclear power generation became impractical. As a result no new plants have been brought into operation since 1994 (a much delayed holdover of the earlier era). An old plant damaged by fire in 1975 was restarted in 2007. Nuclear generation of electricity has stalled at about 20% of the U.S. total.

Since the 70's the public has seen decades of safe nuclear plant operation. This has destroyed much of the fearmongers influence, but has not removed nagging doubts from the earlier period.

Many people genuinely concerned about the environment have reconsidered their opposition to nuclear power generation. After seeing the environment degraded by coal power generation and the vast superiority of nuclear power, many have become supporters.

Environmentalist James Lovelock says "I am a Green, and I entreat my friends in the movement to drop their wrongheaded objection to nuclear energy."

A founding member of Greenpeace, Patrick Moore said in 1976 that nuclear power plants were "the most dangerous devices that man has ever created. Their construction and proliferation is the most irresponsible, in fact the most criminal, act ever to have taken place on this planet." He now calls for their construction as an essential part of our energy supply.

Meanwhile, improvements in operation and refueling efficiency have made individual plants a good deal more productive during their lifetimes, and the total amount of electricity produced has increased even though a few plants have been shut down.

At the same time the exceptional profitability of nuclear plants in a time of high fossil fuel costs has started a resurgence of applications for nuclear plant construction.

It appears the limiting factors in the near future will be:

- a shortage of nuclear professionals
- the skilled workforce necessary for construction
- a global shortage of high-quality components and materials.

But let's step back and review what allows these plants to produce so much power.

How does nuclear power work?

Fossil fueled plants *burn* (italicized words are further described in the Glossary) fuel to produce heat that is used

- as hot stream of combustion gas and air, or
- as heat for steam production

to turn a turbine connected to a electric generator.

Nuclear stations use a nuclear *fission* reaction that produces approximately 2.7 million times as much heat as burning coal.

This extremely concentrated form of energy is a direct consequence of utilizing natural nuclear forces (rather than molecular reactions at the atoms electron shell) to generate heat. It brings Einstein's equation: $E = mc^2$ dramatically into play. Because the speed of light (c) is 3×10^{10} cm/second, the squared term is very large. Applying his equation to the conversion of a single gram (1/454 of a pound) of matter into energy we get (after converting units) 25 million kilowatt-hours. This is approximately the electrical consumption of one million people in one day.

Since the nuclear reaction releases so much more energy, the quantity of fuel required is a great deal lower. This remarkably small fuel quantity affects:

- extraction costs
- purification
- handling
- waste disposal

- human health
- environmental health

The *fission* reaction most commonly used, splits atoms of uranium-235 into smaller atoms. These fission fragments are often *radioactive* nuclei that decay on many time scales to more stable forms.

In nature uranium-235 is only found as 0.7% of any uranium deposit. The other 99.3% is uranium-238. *Separation* of the two *isotopes* is very difficult since they have the same chemical properties and nearly the same mass.

For military purposes *enrichment* proceeds to about 90% U-235 in order to produce the dense concentration necessary to permit the rapid, self-sustaining, *fission* chain reaction in an atomic bomb. To cause this extreme effect, sufficient U-235 is brought together with explosives at a rate faster than it can heat up and force itself apart.

Enrichment for power purposes – usually to 3-5% U-235 – is sufficient to permit self-sustaining *fission*. It is not concentrated enough to be used for military purposes. Without costly further refinement it is impossible to get power reactor fuel to generate a nuclear explosion.

Viva la différence

	Bomb	**Power Plant**
U-235 concentration	90%	3-5%
Compression	explosives	none

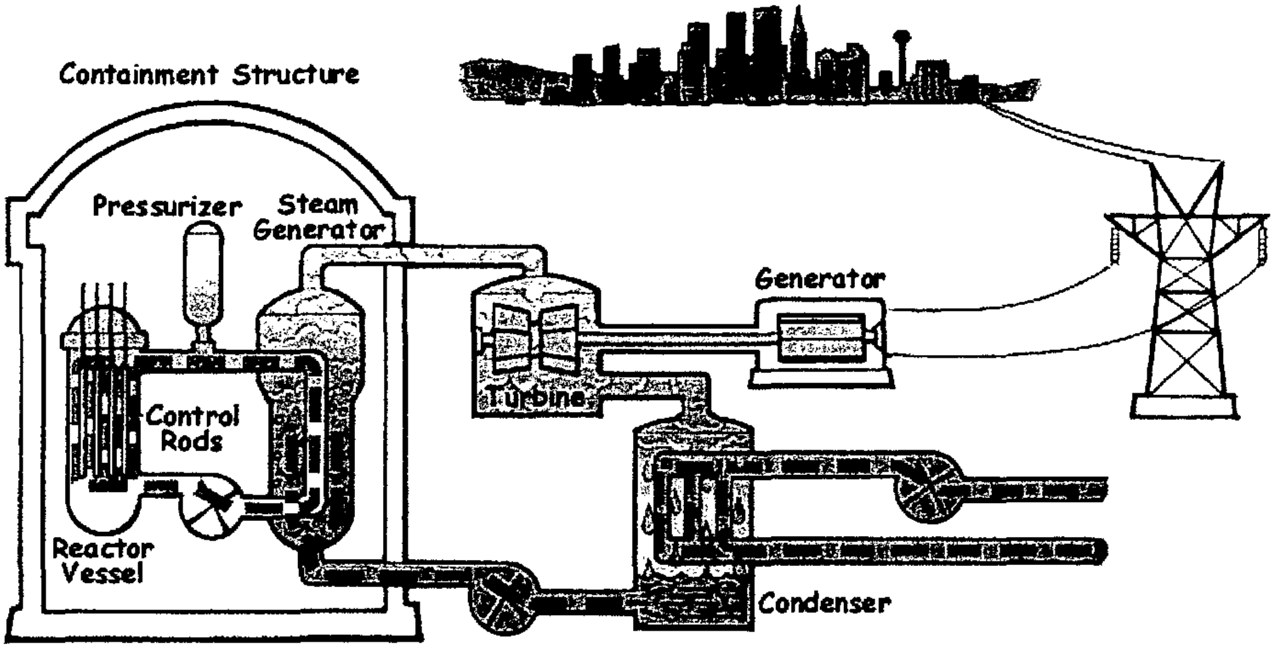
There are a number of reactor designs and new ones are being developed continually. One Canadian reactor type (CANDU) can use un-enriched uranium as fuel but requires the expensive production of deuterium oxide ("heavy water") instead.

The U.S. does have the world's largest number of plants – 104 reactors in 31 states producing about 20% of our electric power. These reactors were ordered prior to the 70's, before nuclear hysteria stopped construction. These plants were initially licensed for 40 years and most will probably be licensed for another 20 years.

The 438 reactors around the world include 2 in Lithuania that produce 83% of its power and 59 in France that produce 78% of its electricity. Even South Korea derives 36% of its electricity from its 16 nuclear reactors.

Features of a nuclear power station.

The pressurized water reactor (PWR) is the most common design in the U.S. (69 reactors) so I will describe its basic layout.



U.S. Nuclear Regulatory Commission

Fuel rods containing encapsulated uranium dioxide pellets are suspended in a matrix inside a heavy steel pressure vessel (usually about 6" thick). The *fission* reaction in the rods heats water to 322 degrees Centigrade at over 2000 psi. The water in this primary loop circulates through a heat exchanger (steam generator) to make steam. *Control rods* of a strong neutron absorber are suspended above a number of open fuel positions in the fuel matrix. They can be partially inserted to control power level or fully inserted to stop the reaction.

Lower pressure steam exits the steam generator (and the containment structure) to drive a turbine linked to a generator to produce electricity. The used steam is condensed and returned to the steam generator.

A very thick reinforced concrete *containment* structure surrounds the reactor and the primary loop to prevent any significant release of *radiation* in the event of a major failure.

This basic description does not mention significant redundancy – a fundamental part of reactor design to keep it in fail-safe mode.

Chernobyl.

All U.S. power reactors are *under-moderated* so any increase in reactor temperature above normal levels causes the reaction to slow down. Since temperature increases expand the moderator and decrease its density, *under-moderation* insures that the number of slow neutrons needed to sustain the chain reaction is reduced. This helps keep the reactor at the correct operating temperature. If a pipe breaks water temperature goes up and the reaction is suppressed.

The Chernobyl design had a "*positive void coefficient*" that violated the under-moderation design constraint. This allowed the reaction to continue as the heat increased until the moderator caught fire and a chemical (not a nuclear) explosion blew radioactive material into the atmosphere. (Chernobyl had no containment vessel). It is important to understand that western-style power reactors are designed to avoid a Chernobyl type accident.

Three Mile Island.
The incident at Unit 2 of Three Mile Island (an 880 MWe pressurized water reactor) was the worst nuclear power accident in U.S. history. A valve shutting in the line from the condenser to a pump in the *secondary water system* plus four consecutive operator errors caused meltdown of half the reactor's fuel. The fuel never escaped the reactor vessel and the containment building held in almost all the radioactive material. A small radiation release occurred when a tank overflowed before *containment* was shut down. The released radiation did not reach the level we experience from nature in ordinary life. No one was killed and the only danger to the public was unwarranted anxiety.

This incident shows that a significant failure followed by successive incorrect operator actions endangered neither the operators nor the public. The *fission* reaction shut down as the plant design intended and only operator errors in handling the residual heat caused plant damage. The operator information that permitted the errors has been corrected in existing plants. New designs now feature better operator information and make much better use of passive safety systems. The last thing reactor owners want is a damaged core at their plant.

A Comparison of Chernobyl & TMI Designs

	Chernobyl	TMI
Moderation	Over	Under
Effect when overheats	Fission continues	Reaction slows
Residual heat	Fuel rods melt, graphite moderator burns, chemical explosion	Fuel melts in vessel, no explosion
Radiation dispersal	Open to atmosphere	Held in containment

Three Mile Island's real damage was psychological and occurred in subsequent years. It aided the virtual shutdown of nuclear power plant construction and thus exposed the public to the far greater dangers of fossil fuel power generation.

Other reactor designs.
The PWR design discussed above is the most widely used and updated versions have been certified by the Nuclear Regulatory Commission (NRC). A boiling water design (BWR) has also been certified.

The smallest of these certified designs is a 600 MWe unit. Since this is larger than the entire generating capacity of Chugach Electric, other designs must be considered.

Many of these more modern designs promise greater operating efficiency, better fuel utilization, and lower construction cost. They do entail greater political risk however, since certification is by no means assured.

In the 165 to 325 MWe range several High Temperature Gas-cooled Reactors (HTGR) are in the pre-certification stage. One operated in the U.S. from 1974 through 1989 and another in Germany. Some more recent designs use fuel pebbles which are continually cycled in and out of the reactor to check for possible replacement. This should bypass the 20 day refueling period every 1.5 to 2 years that takes most reactors off line.

Many designs exist for liquid-metal-cooled-fast-reactors which greatly extend fuel life. Sodium, lead, or lead-bismuth are the metals of choice. Some of these designs are to be factory built, transported to the site and installed below ground. The one proposed for Galena, Alaska will maintain an outlet coolant temperature of 510 degrees C and have a generating capacity of 10 MWe for 30 years without refueling. It also is designed to have a 50 MWe version.

Many more designs have been proposed and some prototypes built, but commercialization has been slow in an uncertain regulatory environment.

Cost comparison.

Costs for any form of power generation consist of:

1) facility construction
2) fuel price
3) operation

Over the 40 to 60 year life of a plant the ratio of these costs depend strongly on the technology used. Typically a natural gas plant is cheap to construct but the fuel is expensive. A nuclear plant is expensive to construct but has very low fuel costs.

Operations costs are modest for natural gas generation, and higher for coal plant operation. The cost of operating a nuclear plant is high, in part, because of intense government regulation. If coal plants were subject to the same sort of safety and health scrutiny none would be able to operate.

Plant costs.

Nuclear plant utilization has been continually pushed higher and is now over 90 %. This is in spite of shutdowns for refueling that take about 20 days. Shutdown frequency is currently moving from 18 months to 2 years.

Construction figures for nuclear plants in the United States are hard to come by since no plants have been built under the current economic and regulatory regime.

Under the designs and regulation prevalent in the 70's operators saw their costs soar as the anti-technologists of the day used every sort of misinformation to delay construction. The U.S. Nuclear Regulatory Commission (NRC) gave in to far too many uniformed complaints. They often approved a set of plans only to change their mind after construction had started. The operator then had to tear out part of the construction and build again. In at least one notorious case the regulators once again changed their mind mandating demolition and reconstruction in the way it had been originally constructed.

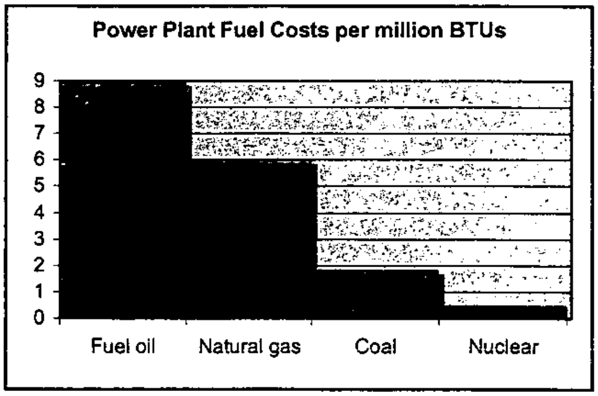
The NRC is now approving standard reactor designs and some designs can have major pieces factory built before moving to the site. Thus there is great hope that late changes and significant plan revisions can be avoided.

A 2004 estimate suggests that coal fired plants cost about $1100/*kWt* (see glossary) while a modern pressurized water plant built under U.S. regulatory control is expected to cost $1700/kWt.

Fuel costs.

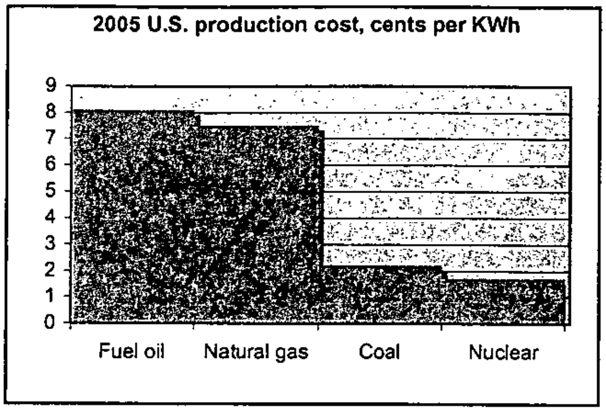
The low fuel costs for nuclear plants mean they are relatively insensitive to changes in the price of fuel. A doubling of the cost of uranium will typically raise electricity costs by 7%. Doubling natural gas prices would add 70% to electricity produced from that fuel.

In these days of rapidly increasing prices of gas and oil, nuclear plant operators across the United States are making great profit margins. Even in the 1990's the Vogtle twin reactor stations (SE of Augusta GA) were producing 15 billion kW-hours per year for 2 cents and selling it for 5 cents. Hauling away $450 million in profit each year is a nice problem for their investors.



Operating costs.

These costs vary all over the map depending on plant type, age, and regulation. Perhaps the best way to look at this uses actual production costs (fuel plus operating costs) across the U.S in 2005:



The numbers have escalated recently for fuel. The trends over time can be seen in the chart on the next page. They suggest that using oil or natural gas could be painfully expensive over the long term.

Fuel supply.
The United States has hundreds of years of coal available at nearly current costs.

Natural gas supply is a more difficult question as price has escalated over 3 times in this decade. Speculation about significant additional supplies is common. The largest methane sources such as the deep ocean, require significant new technology. However, plans for plants with a 40-60 year life must avoid speculation on potential future sources. Estimates must assume escalating costs that likely will make these plants even less competitive than they are today.

The U.S. uses uranium in a "once-through" fuel cycle. That is, we discard the 99.3% of uranium that is U-238, all of the plutonium-239, and the residual uranium-235. This limits the known high-grade supply to several hundred years.

The U.S. supply of nuclear fuel can be greatly expanded if reprocessing is permitted. Breeder reactors would produce more fuel than the U-235 they consume in generating electricity. With reprocessing the available supply could be extended to thousands of years – far in excess of the supplies of any fossil fuels.

The decision to use the once-through fuel cycle was a political one in the emotional period of the 1970's. Other countries made the opposite decision. Perhaps it is now time to try and reclaim our former leadership in this area and assure the world of adequate power into the distant future.

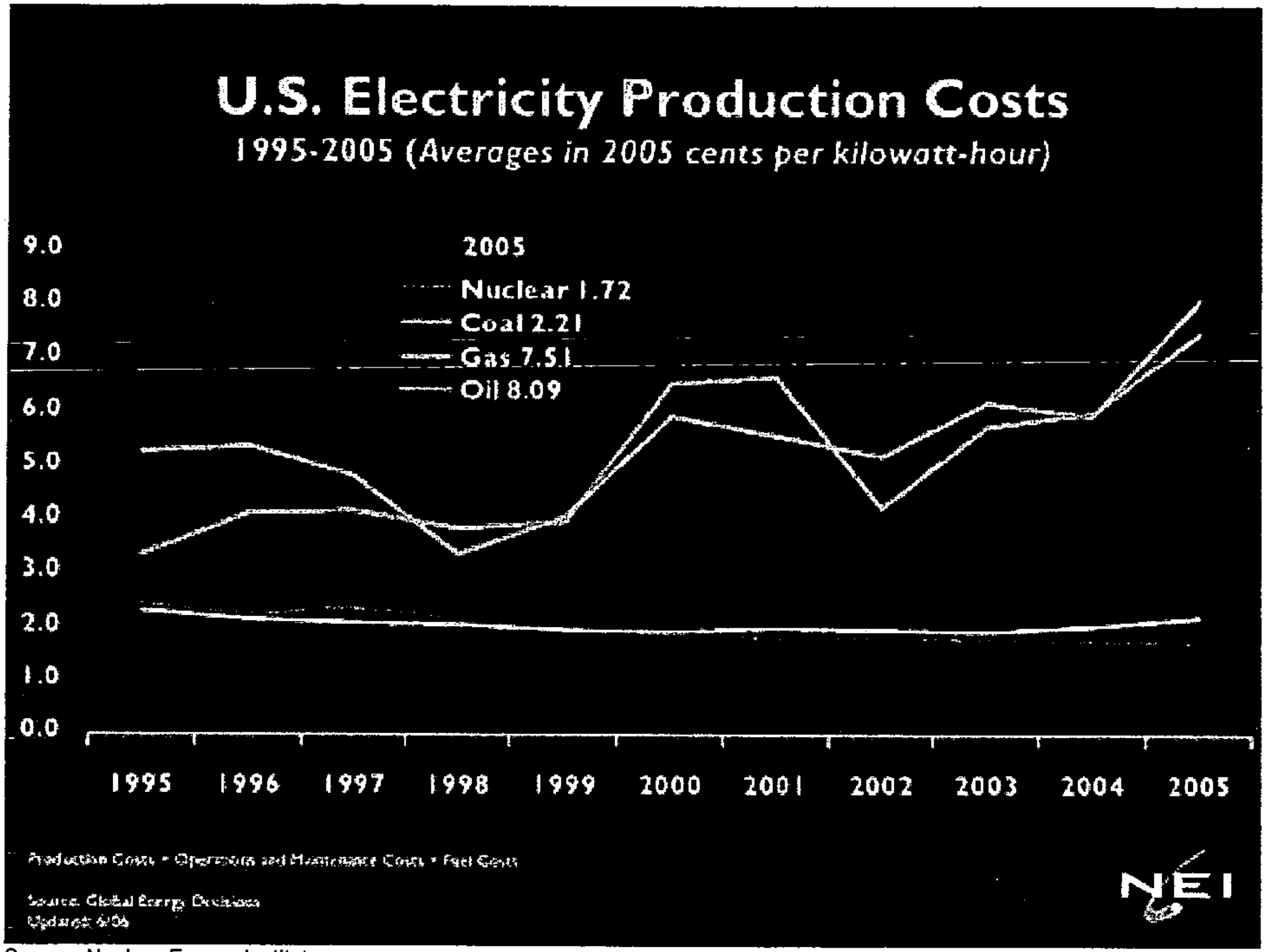
External costs.
Claims have been advanced that nuclear power generation imposes external costs on the public that are not captured in rate-payer charges. This is much less true in the case of nuclear power than in other forms of generation. The intense regulatory environment caused nuclear power generators to provide advance funds for many items (shutdown, waste disposal, catastrophic and health insurance) that are often deferred or foisted on the public by other power generation techniques. Under the current regulatory and tax environment nuclear ratepayers more fully finance (internalize) cost than the other generation techniques. A 2003 study by the Organization for Economic Co-operation and Development (OECD, NEA4372) concluded that although costs estimates for fossil fuels and biomass externalities are rather crude they are at least 10 times higher than for nuclear power.

Once the health and safety concerns for fossil fuel generation are studied/regulated with the attention that nuclear has received, we can expect the internalization of these costs to add significantly to the rate-payers bill.

Overall costs.
In spite of construction cost estimating difficulties in 2005 the OECD did come up with generation cost estimates for a number of countries. For the U.S. they estimated (for 2010) overall generating costs in cents/kWh with a 40 year plant lifetime, a 85% capacity factor, and a 5% discount rate as:

Nuclear	3.01
Coal	2.71
Gas	4.67

Other sources place overall nuclear costs at or slightly below the cost of coal production. If the uncertain initial plant construction is factored out nuclear is significantly cheaper.



Source: Nuclear Energy Institute

Note: the above data refer to fuel plus operation and maintenance costs only, they exclude capital, since this varies greatly among utilities and states, as well as with the age of the plant.

Summarizing the various fuels for generating electricity

We have not previously included solar and wind power in our comparisons because they are not capable of providing the continuous baseload power necessary to a modern society. People who have not done the arithmetic keep hoping that technological advances will make them effective. Such hopes founder on problems of:

- intermittency
- low energy density
- seasonality
- poor integration with existing sources
- environmental impact.

Anyone who retains such hopes should view the very informative DVD "Nobody's Fuel." Solar and wind will remain minor sources, useful where utility power is not available and battery storage can cover the many unproductive periods.

Commodity	Advantages	Disadvantages
Coal	• relatively low costs • plentiful supplies	• produces air and water pollution • produces ash requiring disposal
Hydropower	• low pollution • very low operating costs	• may cause the modification or destruction of ecosystems • most potential hydro locations are already developed
Natural Gas	• low generating costs • low capital costs	• supply and price can fluctuate • produces air pollution, though less than some other sources
Nuclear	• does not produce air or water pollution during operation • low operating costs	• produces radioactive waste requiring carefully controlled storage • high initial capital costs
Oil	• easy to use and transport	• produces air and water pollution • supply and price can fluctuate • relatively expensive
INTERMITTENT SOURCES (potential scale too small for baseload power)		
Solar	• inexhaustible supply • no pollution during operation	• large scale projects require much land • very expensive • requires operating full backup plant
Wind	• inexhaustible supply • no pollution during operation	• large scale projects require much land • wind doesn't always blow when electricity demands are high • requires operating full backup plant • extremely noisy • too small-scale for urban areas

Cameco, 29 June 2006

Safety & health while generating electricity.

Nuclear power generation has tremendous health benefits to the general public. It displaces more polluting fossil fuels for a very significant reduction in illness and death, as well as a drastic reduction in climate altering gases. Nuclear power also has safety benefits to those engaged in the whole fuel preparation and power generation cycle. This would not be apparent if one listened only to opponents who have tried to prevent use of this new advanced technology.

All power has risks although being without power is even more detrimental to one's health. Estimates differ, but in the absence of electricity and fuel-based transportation our planet would see 2/3 of the people starve and the rest live shorter disease ridden lives of constant drudgery.

Therefore any risk estimate must be a comparison between viable technologies capable of significant power production. At present these are only coal, natural gas, nuclear, and hydro.

Hydro safety.
Hydro power generation poses more of a safety problem than a health problem. When dams rupture they affect the general public considerably.

In Vaiont near Belluno, Italy a mountainside collapsed into a reservoir and caused flooding. It killed 2,000 people and made 50,000 homeless. A number of dam breaks in the U.S have each killed hundreds of people. Careful risk calculations indicate major hydro accidents are least 10,000 times more likely than major nuclear accidents.

Health problems are the most significant characteristic of the other three power generation technologies.

Coal safety.

Coal causes, at present, an estimated 24,000 to 70,000 premature deaths in the U.S. each year from air pollution. In addition there are deaths in coal mining, and waste disposal. Even coal transport kills about 100 people a year. Burning coal releases natural radioactivity directly into the biosphere far in excess of that permitted from a nuclear plant. I have seen no estimates for the dangers from the toxicity of mountains of ash produced by burning coal.

Natural gas safety.
Natural gas produces significantly less air pollution than coal but still features many of the same atmospheric pollutants at lower concentrations.

It is also a storage hazard in many cities, particularly where LNG is delivered to tanks near a city's population. Delivery pipelines have ruptured, killed people and caused spectacular fires.

Nuclear regulation mandates a much higher level of public safety than natural gas. While the nuclear regulators were insisting on plant changes that might save one life per year at a cost of 800 million dollars, no one was willing to spend the money to move natural gas storage out of population centers. The cost of this natural gas safety precaution was calculated as less than $1,000 per life saved.

Nuclear safety.
Nuclear power generation has substantially lower risks. In fact it has had to rely on calculated theoretical dangers since no one has yet been killed in U.S. power reactor operation. This exemplary record persists even though we use nuclear generation for about 20% of U.S. power. Some reactors have been operating for several decades. Other countries have not had quite as safe an operating history, but still have far surpassed the safety records amassed by other generating techniques.

Nuclear health and safety concerns revolve around the release of dangerous levels of radiation. The maximum radiation level permitted at the plant's perimeter is less than 4% of natural background radiation.

Underground uranium mining is another matter. That and other underground mining that encounters high radon levels can produce elevated lung cancer risks. Since high-grade uranium mines often have higher radon levels than the average mine, the cancer risk is also higher if ventilation is inadequate. This risk appears to be lower than the other occupational risks of underground mining, but are not stopped by ending the exposure period. This area is subject to a lot of controversy and compensation to former miners is in dispute. Almost all of this exposure occurred in the early mining for WWII and the early cold war. Meanwhile a very much larger number of coal miners developed black lung disease.

Most current uranium mining is open pit with notably lower risks. About one-quarter of world uranium mining is now done by in-situ leaching, so the risks are very much reduced. The remaining problem is potential groundwater contamination.

Estimates of radiation danger used in the industry and in the NRC are very conservative and are known to significantly overstate the problem of low-level radiation.

Canadian experiments in cell biology actually show that cell survival is <u>improved</u> with some low levels of radiation.

An apartment complex in Taiwan was mistakenly built with radioactively contaminated reinforcing rod. The many 20-year residents showed abnormally high <u>resistance</u> to cancer.

Survivors of intense radiation at Hiroshima and Nagasaki have been followed for two generations to look for excess deaths or abnormalities in subsequent generations. The numbers were <u>not changed</u> by the radiation.

Nuclear waste disposal has received a lot of political hype. Unfortunately the government is involved and they have been charging fees to provide a facility for long-term storage. It has become a political football even though the technology is comparatively easy. Industry has paid many times the cost of the storage facility at this point. Meanwhile plants are storing waste fuel assemblies in water pools or in steel and concrete casks. Both protect the public very well but water storage requires some care and the casks will need renewal after a few thousand years.

The big problem is space since land on which some plants were built assumed they could store the waste off-site after 10 or 20 years.

The exceptional safety and health benefits of nuclear plants are a result of the extremely concentrated nature of the fuel. This means that the very little bit that is used can have exceptional care taken in its preparation, use, and disposal.

Alaska's chance for getting nuclear power.

Alaska and particularly Anchorage have a good opportunity to use cheap and plentiful nuclear power for the following reasons:

1) We have a politically powerful congressional delegation that can assist in expediting the path through the onerous federal regulatory requirements.
2) Anchorage citizens have a one of the highest educational levels of major cities across the United States. They are more open to newer technology. These features should reduce the resistance to new technology.

Chugach currently has 499 megawatts of natural gas fired capacity and 66 megawatts of hydro generation. The smallest plant fully certified by the NRC is a 650-megawatt facility. Plants of 180, 360 megawatts are in pre-certification phase and designs have been announced for plants at the 10, and 50 megawatt size. The last three are called nuclear batteries since they are manufactured and sealed with no re-fueling or maintenance for their 30-40 year life. The larger units would require cooperation among all the South-central electric utilities, but do produce the cheapest power.

Recommendations to Chugach Electric:

1) Engage a competent nuclear engineering firm to study the potential for using nuclear generation of electricity to serve south-central utilities.
2) Hold discussions with other utilities about their future power requirements.
3) Start discussions with our Congressional delegation about federal regulatory issues.
4) Investigate the potential for nuclear plants of a size appropriate to the Alaska bush.

Should anyone ask why consider nuclear power generation you can say with full justification –

> **"Nuclear generation is the safest and cheapest way to provide significant long-term power."**

Dr. Anderson is an Anchorage, Alaska businessman and physical chemist. He wishes to thanks Ed Johnson of Sunnyvale, California for his technical fact checking and editorial suggestions and Dana G. Anderson of Anchorage for her many formatting and readability suggestions. He claims ownership of any remaining errors.

(Glossary below)

Glossary

Burn – An exothermic chemical reaction that rapidly oxidizes fuel to produce both heat and various oxides. Since the fuel is impure it also produces unwanted by-products. As a chemical reaction involving only non-nuclear forces it also produces modest amounts of heat per reaction and so requires a large volume of fuel to generate practical amounts of electricity.

Containment – U.S. reactors are built inside an extremely strong reinforced concrete building that houses the reactor vessel, a steam generator (if any) and much of the safety piping necessary to remove the residual heat in a reactor once it is shut down. The number of openings are kept to a minimum and can be blocked to isolate the reaction vessel and nearly all radiation in case of a major failure.

Control rods – Rods that may be inserted into a reactor to slow or nearly stop the fission process by absorbing neutrons. Boron is often used since it absorbs rather than slows neutrons.

Enrichment – The process of increasing the percentage of U-235 in natural uranium (which is a mixture of 0.7% U-235 and 99.3% U-238).

For light water reactors uranium-235 is increased to 3–5 % or 4 to 7 times.

For military applications the enrichment is carried to about 90% U-235.

Fission – Most atoms ignore or absorb free neutrons that come their way, however the uranium-235 nucleus splits instead. The ensuing nuclear reaction breaks a uranium-235, uranium-233 or plutonium-239 (produced when U-238 captures neutrons) into 2 lighter mass fragments generally in the mass range 72 to 160. It also produces on average about 2.4 free neutrons (from U-235) of which one is needed to initiate the next fission.

All fragments possess tremendous kinetic energy. This kinetic energy is absorbed and converted to heat (about 2.7 million times that from chemical burning).

Isotopes – Atoms with the same number of protons, but different numbers of neutrons.

At the first level of subdivision atoms are composed of protons, neutrons and electrons. In a neutral atom the number of protons equals the number of electrons.

The number of protons gives the atom its chemical properties and its atomic number.

Neutrons have no charge and their number varies but usually increases significantly for atoms with large atomic numbers. For example the most common form of hydrogen (1 proton = atomic number 1, $^{1}H_{1}$) has no neutrons. Its less common isotope - deuterium adds one neutron ($^{2}H_{1}$). The most common form of uranium (atomic number 92) has 146 neutrons for a mass number of 238 (92 protons + 146 neutrons, electrons are too light to count).

Seven tenths of one percent of natural uranium has only 143 neutrons and so this isotope is called uranium 235 ($^{235}U_{92}$). While having the same chemical properties as uranium-238, uranium-235 has different nuclear properties and a slightly lighter nucleus. When reacted with fluorine to form UF_6 for separation, the mass difference is less than 1%!

Isotope separation – Since enrichment of natural uranium is needed for most reactor designs several methods of separation have been developed, which depend on the difference in the mass of U-235 and U-238.

Starting in WWII the U.S. used gaseous diffusion to enrich the fraction of U-235. This requires vast plants since each stage only achieves a very slight increase in the percentage of U-235. Since the capital investment has been made, the U.S. continues to use this capability although it will likely be phased out because of high operating costs.

With the development of stronger materials and superior bearings, most other nations use about 3,000 very-high-speed, cascaded, centrifuges to separate the isotopes. Most countries use this technology and the U.S. now has a demonstration plant and will build a full-scale centrifuge separation facility by 2012.

kWt – Kilowatt thermal. In our discussion it is the highest power rating of the heat source. It should be distinguished from kWe which is the power rating of a plant in terms of its highest possible electrical output. It is not possible to convert heat to electricity with 100% efficiency. Conversion efficiencies of 30% or more are considered good. The energy difference is usually dissipated as waste heat. Some plants use the heat directly or a portion of it (such as nuclear submarines), so the kWe term does not describe the entire potential of a electrical generating plant. However, if all possible heat is used for generating electricity the kWe term offers a comparison that incorporates plant efficiency.

Moderator – Since slow moving neutrons are more likely to cause the next fission event rather than escaping the reaction vessel a speed reducer (moderator) is used which slows down the neutrons without absorbing them. Water is such a moderator and is used in many reactor designs. U-238 also assists as a moderator.

Positive void coefficient – Some older Soviet power reactors and some research reactors are designed with a positive void coefficient. In these reactors the reactivity increases if the moderator which is often also the coolant decreases in density or "voids." For a description of a how one achieves a "negative void coefficient" see *under-moderated.*

Radioactive – Many isotopes are not stable and emit radiation in the process of moving toward a stable nucleus. Elements above bismuth (atomic number 81) have no known stable isotopes although the rate at which they decay varies a great deal.

In reactor processes we are concerned with 4 types of radiation:

1) Alpha particles are the nucleus of a helium atom (2 protons and 2 neutrons). The mass of the remaining nucleus is 4 units smaller and its atomic number is lower by 2 units. Alphas are very active and interact with everything so they do not go very far. If you hold an alpha source in your hand the dead layer of skin or a single sheet of paper will stop all alpha particles. They are a health hazard only if ingested or inhaled.

2) Beta particles are high-energy electrons emitted by the nucleus as it converts a neutron to a proton. They penetrate better than the alphas and do mess up the electrical nature of atoms, but have so much smaller mass that they don't knock things around like alphas.

3) Gamma rays are at the high end of the electromagnetic spectrum and carry a lot of energy. They are sufficiently penetrating that they can look through steel to find cracks or voids. They can easily knock an electron out of an atom and create a charged ion. This is great for killing bacteria but has the same effect on human cells. Too much gamma radiation will kill you.

4) Neutron radiation features a neutral particle, so they don't grab electrons. As emitted from a fission reaction they travel at very high speeds and do bump into anything in their path, transferring their kinetic energy to the target. Neutron bombardment can change the properties of materials in unfortunate ways such as making them more brittle. Therefore, careful material selection for reactors is important. Zirconium metal has shown remarkable durability in a high neutron environment. When a neutron is absorbed into an isotope it becomes an isotope with one higher mass number.

Now look at nuclei that produce radiation or are formed by it.

One <u>half life</u> indicates the period in which half the nuclei in a sample will emit radiation and decay to another element or isotope. Nuclei with short half-lives are very radioactive, but are gone in short order so we must deal with their products. Nuclei with long half-lives will be around a long time, but are only weakly radioactive.

For example: Uranium-238 has a half-life of 4.47 billion years, which accounts for its weak radioactivity as well as its continued presence on our planet long after its formation. On the other hand U-239 has a half-life of 23.5 minutes, so the only reason we ever have it is because it is formed routinely from U-238 when that isotope absorbs a neutron. On the other hand U-239 gives off a beta particle leaving behind an additional proton and becoming Neptunium-239. Neptunium-239 is not stable either and has a half-life of 2.35 days. It then does another beta emission gaining the proton needed to become plutonium-239. With a half-life of 24,100 years it's going to be around for a long time unless we put it in a reactor. Plutonium-239 fissions as well as U-235. Plutonium-239 from most power reactors is contaminated by Plutonium-240 making it less suitable for a bomb.

Since many of these fuel elements and products of the fission reactor are unstable and emit radiation, it is important to shield surroundings from the more intense sources. Unlike toxic chemicals, which can often be changed to benign forms via chemical reaction, radiation is a nuclear property and remains, regardless of the chemical compound in which the atom is bound.

Secondary water system – In pressurized water reactors there are two types of water circulation loops. The primary water system circulates the high-pressure water through the reactor and the steam generator. The secondary water system circulates the steam/water from the steam generator through the turbine and condenser and back to the steam generator. Both loops are served by redundant piping.

Under-moderated – As a control and safety feature all U.S. power reactors (and almost all around the world except some old Soviet designs) are designed so an increase in power beyond the optimum is met with negative feedback.

One feedback mechanism is to limit the amount of moderator allowed adjacent to the fuel elements. Since heating a limited moderator (usually water) decreases its density, it also decreases its ability to slow neutrons enough to allow fission. The amount of moderator in the reaction vessel is carefully computed for the desired operating temperature and helps maintain that temperature without any external inputs.

Rupture of a primary pipe also decreases the water slowing the reaction. Of course other provisions are necessary to deal with the residual heat if the primary loop is non-operative since the water is also the heat transfer agent.