CRITICAL HOUR:
THREE MILE ISLAND, THE NUCLEAR LEGACY, AND NATIONAL SECURITY

by Albert J. Fritsch, Arthur H. Purcell, and Mary Byrd Davis

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Dedication

We would like to dedicate this book to the thousands of citizens who during the past half century have sought to publicize the dangers of nuclear power facilities.

Acknowledgments

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Introduction

The 25th anniversary of the Three Mile Island (TMI) nuclear accident is a fitting opportunity to renew the recommendation that narrowly missed being approved by the Carter-appointed TMI Commission a quarter of a century ago, namely, the request to phase out the nuclear power industry in this country. Having lost a golden opportunity then, we still have precious time left to reconsider the recommendation. Now at the beginning of the 21st century several European nations are planning and becoming committed to phasing out nuclear power plants. It is time for our country to follow their example and take this necessary step for the sake of national security and the health and safety of our citizenry.

Goal of the book: This truly is the Critical Hour, the time to go cold turkey on nuclear power generation and to decommission reactors, the time to end the myth of the peacetime atom, and the time to turn attention to safer and more secure renewable energy sources. Too much time has been spent trying to license, make safe, and upgrade aging nuclear power reactors at over a hundred powerplant sites in our country. We must make a difficult comprehensive national decision about nuclear power - and this book offers the reasons and background necessary to reach such an important goal and consensus. The hope is that citizen pressure from communities located near nuclear power sites will start to arise and spread through other responsible public-spirited citizens across the land. We seek to focus informed and energetic activists once again after a two-decade hiatus on this important issue.

There are several reasons why this goal should be urgently pursued at this time. Human error could again cause a partial or complete meltdown, a repetition of TMI or Chernobyl. Irradiated nuclear fuel continues to pile up at nuclear power plants, and no repository is ready to receive materials or has even been determined to be in a safe location. Furthermore, many of the current irradiated-fuel storage areas are soft targets for post-September 11, 2001 terrorist attacks, a threat never dreamed of by those early proponents who bragged that the energy from the atom would make electricity too cheap to meter. What a burden that is hanging over us!

Questions: As we grow in collective wisdom, we are able to ask more critical questions. Why hold entire metropolitan areas hostage to the whims of terrorists who would be unafraid to die while damaging a nuclear facility? Why risk thousands of innocent lives and accompanying property damage that could run into the billions of dollars all in order to continue a costly and unsafe manner of generating electricity? Why continue to ask national forbearance for the sake of an outdated nuclear power industry, when safer alternatives are so accessible and their potential is increasingly being realized? Why not turn to wind power, the world's fastest growing energy source, along with solar applications and energy efficiency, which collectively could match U.S. nuclear power plants several times over? Must we wait until a major calamity occurs before we act?

Solutions possible: Critical Hour tells the story of what has occurred in the past, and promises that things can be safer in a very short time, provided Americans begin to act now. History

shows that the problems with nuclear power have grown with the years; they are the crisis-ridden problems of a people addicted to energy, no matter what the source, and many of these users are too distracted to make proper decisions. Acceptance of our present position is the beginning of a proper recovery, and our book strives to cast light on our present condition.

Audience: Critical Hour is written in a conversational manner for a broad span of readers: from the unsophisticated to the more serious with accompanying references. We, the authors, would like to say it is directed to the general American audience for we as a committed people, are energy leaders in the world. The conviction is that a democratic people, and its decision-makers, must, as one body, put nuclear power behind them. Having described an ideal general audience, we realize the limitations with any serious work like this one - people find such books hard to read from cover to cover. Thus, while the book is written for all people, we must concede that it is a "specialty" work mainly intended for those who need to be armed to lead local battles to remove nuclear power plants from their respective backyards. Hopefully, the book is a primer that will do this in an easy and readable fashion and will reach an ever broader audience.

Structure of approach: Americans are notorious for forgetting or never learning history in the first place. The rise and fall of the commercial nuclear story is worth retelling, even though older people have lived through the time period. The book is thus divided into three major parts: the Three Mile Accident itself and the subsequent Commission formed by President Carter to investigate the cause spoken from inside the Commissions; the six decade historical span of an ever growing and more complex citizen nuclear power problem, presented decade-by-decade and arriving at the post-9-11 world with its potential terrorist threats; and the practical steps that we can take to leave nuclear power behind, lest we be enticed by current types of nuclear technologies promised by industry to be safer and better. Instead of such empty promises we as a people must decide to choose energy efficiency and viable renewable energy alternatives.

Actions to follow: This book is meant to inspire the activist to readdress the nuclear power plant issues of the 1970s. It is time to distance ourselves from ever more apparent nuclear dangers and pitfalls. The present is the kairos, the supreme moment for action. We, as a people, have been moving towards this decision-making period during the past quarter of a century since the last U.S. commercial power plant was ordered. TMI was the wake-up call and yet we as a people did not respond; the Chernobyl disaster in the USSR was an added warning with its immense suffering and death to residents and workers; however, we did not heed the disaster's message, especially since Chernobyl was a distant place and within a crumbling regime. The terrorist threat is still another and
maybe the last opportunity to respond - but the time is short.

Quick review: Critical Hour charts a course of action as response starting from guilt-ridden Hiroshima and Nagasaki atomic bomb days. It includes a rather immature striving to out-promise the Soviets in an Atoms for Peace program. It includes the hidden expenses of federally subsidized uranium processing and enrichment. It contains the burning shell of the Chernobyl plant, the escaping
radiation of which would kill or injure a quarter of a million people in the Ukraine and Belarus. The

course moves through the 1990s when sleight of hand engineering extended the lives of aging power plants and comes past the shadow of the twisted twin towers of the World Trade Center, to the present moment.

And the present moment is not a comfortable period when it comes to nuclear power. America has over one hundred and ten power plants and processing sites into which a crazed terrorist could crash a well-placed explosive-laden vehicle by land, water or air and hit the plant or stored irradiated-fuel rods causing a catastrophe. Incomprehensible though it may seem in this time of heightened security, these sites are scattered, often poorly guarded and quite vulnerable.

Knowing where we are: This frightful history of actual and possible events demonstrates the necessity of taking a steady course of corrective action. Nuclear power is a forbidden fruit growing on the Tree of the Knowledge of Good and Evil - and it is too complex for mortal creatures like us to handle. But temptations to continue to rely on unsafe technology do not exist in a vacuum; they tend to grow and destabilize entire civilizations - and they are doing just that to us. Merely recounting nuclear power's history has its purpose, and the subject can be fascinating. But this history cannot stand alone. It must be coupled with a way out. Responsible citizens can make a difference and have a far safer environment, and do so through renewable energy use and energy efficiency with no sacrifice of quality of life. Frankly, that quality will improve vastly when nuclear power facilities are shut down and decommissioned.

Critical Hour addresses but does not offer full solutions to the decommissioning problem, namely, the unanswered question of what to do with inactive reactors. There is no easy solution to the problem of decommissioning. The radioactive remnants of nuclear power generation will be around for a very long time, and we are powerless to ensure safeguards over the upcoming centuries. For irradiated spent fuel, neither storage at reactor sites, nor transportation to a "safe" repository is without additional problems.

The authors' experience: We three authors have altogether almost eighty years of experience in the fields of nuclear safety both in this country and in France. One of us has worked on the Three Mile Island Commission, another has written on the commercial nuclear fuel chain in the United States and Europe; a third has taken an active interest in some of the first organizations formed to challenge nuclear power and has maintained a center dedicated to solar alternative applications. The team seeks to bring broad-based experience to the difficult problem of nuclear energy. Thus we, the team, are committed to handling the issue in a holistic manner, something not done in the launching of the commercial nuclear industry devoid of concerns about eventual health, waste disposal, and security issues.

Need for working together: As authors, we do not pretend to be problem-solvers through some superior experience or intelligence. Conversion from nuclear energy will require much input from a large number of experts. The establishment of renewable energy, though it can be done with relative ease, requires creative and optimistic innovators; we can look to European as well as to American experts. Decommissioning will occur cautiously and may require that some facilities be moth-balled while the best solution is awaited. The time is right but short for a collective

undertaking by all our people. We must take a historic perspective and find where weaknesses appear. Prudence calls us to act as a people, to abandon unsafe nuclear power, and to support energy efficiency and renewable energy alternatives that are proven to furnish the safe energy needed today. The public must be educated simultaneously on the growing problems and emerging solutions if there is to be a successful public response. Now is the Critical Hour to do this, and the anniversary of TMI is an ideal launching period.

Chapter I

The Accident Begins

Arthur H. Purcell

A chilling coincidence

March 14, 1978: The *Daily Record* of York, Pennsylvania (a city 15 miles downwind from Three Mile Island) runs a lead story titled "County Unprepared for Nuke Disaster." Its first two paragraphs read:

> York County is not prepared for a nuclear accident at Peach Bottom or Three Mile Island atomic power plants, a six-week-long investigation by the *Daily Record* reveals.
>
> An accident at Three Mile Island could threaten the lives and health of all 15,000 York countians living within five miles of it.

The paper has asked residents if they have "heard of or seen" a copy of evacuation plans for a possible accident. Replies one man living just across the river from TMI: "Don't worry about an accident. You should be worrying about nuclear attack. An accident can't happen."

March 28, 1978 at 4:00 a.m.: It is a cold morning along the wide Susquehanna River in central Pennsylvania. But even at this very early hour the air is filled with excitement. The second and final chapter of the dream of nuclear power at the Three Mile Island generating station has commenced. Unit Two, the twin to a system that has been on line four years, has just "gone critical" - that is, for the first time it has begun a self-sustaining nuclear reaction.

Satisfaction and a mood of celebration pervade the control room and the plant. In nearby Middletown, heart of the TMI community, there is a feeling of pride that both reactors are now on line. The old coal-burning plant in nearby Middletown is now quite obsolete and the community sees itself on the leading edge of energy technology.

Saturday, March 24, 1979 at 8:00 p.m.: It is a blustery evening on upper Wisconsin Avenue in Washington DC. There is some excitement in the air among the crowd standing in line for a new Mike Douglas movie showing at the K-B Janus. It is called *China Syndrome.* The plot will prove a bit far-fetched for most of the viewers: A combination of technical and management blunders threaten a nuclear power plant reactor meltdown that, in the words of Jack Lemmon (playing the control room shift supervisor), could jeopardize an area "the size of Pennsylvania."

Two days later - a few seconds after 4:00 a.m. It is an unusually mild morning along the wide Susquehanna River in central Pennsylvania. At this very early hour America's most serious commercial nuclear power accident is about to begin at Unit Two. The accident is triggered by a minor pump failure that has occurred *exactly* one year - to the minute - after Unit Two's big moment. Over the next few days and weeks the air around Three Mile Island will be threatened by potential deadly radioactive emissions. Confusion, uncertainty, and fear almost immediately grip the Unit Two control room and will soon reign in the community, the region and far beyond.

Edward Frederick would remember that morning like no other. He was one of four people on duty in the Unit Two control room at the time. His subsequent testimony before the President's Commission on the Accident at Three Mile Island (the Kemeny Commission) painted a crisp picture of the pre-dawn emergency with which he was faced:

> Chairman Kemeny: ...Could you give me some idea of how many alarms might have gone off during the first five to ten minutes? Was it like two or 200?
>
> Frederick: In the first few seconds of the accident there were probably several hundred.

In the control room with Frederick were Shift Supervisor William Zewe, Shift Foreman Fred Scheimann, and control room operator Craig Faust. Faust and Zewe would recall the confusion in the following way:

> Chairman Kemeny: ...I would ask you to describe, in your own minds, what the state of your emotions were and the state of your sense of competence to control this event were at say 4:30 or 5:00 on the morning of March 28th while these 200 alarms were flashing and other lights were on?
>
> Faust: I would have liked to have thrown away the alarm panel.
>
> Commissioner McPherson: You would have liked to have thrown away the alarm panel.
>
> Faust: It wasn't giving us any useful information...
>
> Chairman Kemeny: Mr. Zewe, did at any time let's say during the first half hour, any of [you] have a chance to look at the alarm center, or were you so busy you had no chance to to look at it?

Zewe: Quite some time after we had the event I had called the Unit One Shift Supervisor to come over and assist me. And when he came over I asked his aid in looking at the computer printout to try to help us along with the casualty that we had before us...

The "casualty" before these four individuals and the rest of the world would prove to be a situation for which the TMI control room operators had received no training - a "Class IX" accident in the parlance of the Nuclear Regulatory Commission, or a nuclear power mishap involving a sequence of events so unlikely that it did not warrant serious consideration. Yet the impossible was happening at Three Mile Island.

Even though the reactor shut off automatically just seconds after the start of the accident, heat continued to build up from decaying radioactive materials left from the fission process. This heat was just six percent of that released during reactor fission, but it was still substantial. The pump failure, or "trip," that had started the accident, led to a tripping of the steam turbine, which meant that heat would not be dissipated through steam production.

The kettle starts to boil

The water-cooled Unit Two system started to overheat. Three emergency feedwater pumps began automatic operation to add cooling water. Fourteen seconds into the accident one of the operators noted that the feedwater pumps (as indicated by a light) were running. What he did not notice, however, were two red lights indicating that the feedwater lines had been closed (this closing was strictly against regulations) and thus no fresh cooling water could enter the system, despite the fact the pumps were running. So, like a kettle, the Unit Two system slowly headed toward a boil.

Within a few minutes Craig Faust would discover that the emergency feedwater lines had been improperly shut off, but his discovery would come too late. The poor design of the control room instrumentation and the malfunction of one key piece of equipment were to set this Class IX into irreversible motion.

A critical piece of hardware at TMI was something called the pressure operated relief valve, or PORV, which is simply a valve that can be opened to relieve excess system pressure. That morning at TMI, as the system started to boil, the pressure increased and the PORV opened, just as it was supposed to do. The only problem was that when the pressure dropped and when time came for the valve to close, it stuck.

The operators had no easy way of knowing it was stuck. A green light on the instrument panel indicated that an automatic electronic signal had been given to close the valve, but no instrumentation existed to indicate that the physical act of closure had occurred. Thus, while the control room operators assumed the PORV was closed, it remained open for over two hours, letting massive volumes of precious water escape in the form of steam. And the emergency

feedwater lines were still closed. The system continued to boil toward dryness and reactor meltdown.

Faust's discovery of the closed valves brought some needed water into the system and high pressure injection emergency cooling water was also being added. But another control panel design failure, that of the pressurizer level indicator, caused a misunderstanding that would seal Unit Two's fate.

TMI operators had been trained in the importance of keeping a head of steam in the pressurizer, by not letting it fill with water, or "go solid" in control room terminology. The pressurizer determined the pressure under which the cooling system operated.

Once the accident commenced, the pressurizer level indicator seemed to keep showing a rising water level. And the operators became more concerned; the system must not go solid. So what did they do? They started reducing the flow of cooling water into the system. The indicator, in fact, was not showing a rising water level; it was merely indicating that the water was bubbling, like water in a giant coffee pot. As the amount of water in this pot diminished, the bubbling became more vigorous and the pressurizer level indicator appeared to show an increase in water volume, even though the exact opposite was occurring. The result was exposure of the reactor core to extremely high temperatures and subsequent damage to it.

Many months before the TMI accident an Oak Ridge National Laboratory engineer named Michaelson had written a memo warning that this precise situation was possible and that a nuclear cooling system that was boiling dry could be mistaken for one "going solid" if control room operators relied on the pressurizer level reading. This memo, which later became known to accident investigators as the Michaelson Report, received only cursory attention at the Nuclear Regulatory Commission (NRC), the federal government's nuclear watchdog, and was passed on to nuclear utilities without any urgency. James Floyd, Unit Two Operations Supervisor did not know about the Michaelson Report until two or three weeks after the accident.

The combined effect of a reactor trip from a minor pump failure, two closed valves, one sticking valve, poor control room design, and data misinterpretation by control room operators never trained for the kind of non-routine malfunction that was occurring on March 28, l979, was this country's worst commercial nuclear power accident.

As Middletown, Pennsylvania, awoke on Wednesday, March 28th, l979, it awoke, along with the rest of the world, to a new and threatening era in nuclear power - the start of serious questioning about whether the risk that nuclear power poses can be justified, of what should be done with massive volumes of contaminated fluids and materials that result from failed or worn out nuclear reactors. 4:00 a.m. on that day marked the dawn of an era of critical thinking on how this country could move into an environmentally and economically viable mode of nuclear power decommissioning.

Between the time the residents of Middletown had retired the night before and arisen that

morning, a reactor had partially melted down, TMI's containment buildings were awash in a million gallons of radioactive waste water, and radiation of unknown quantities, character, and distribution patterns had been released into the air over central Pennsylvania. The country's (and, until Chernobyl) history's most severe commercial nuclear power accident was just hours old but would have repercussions for decades to come.

Nothing official happened that Wednesday. That is, few people changed their routines because of the accident. There was no call for an evacuation, no official warnings or explanations. In fact, not everyone knew there had been an accident. School children stood outside in the morning and afternoon waiting for buses and during the day for recess. Farmers tended to outdoor spring chores. In the fertile Amish country to the east of Three Mile Island women - old, young, pregnant, and unmarried - worked alongside their men in the fields. A local station had reported an accident at TMI, but hastened to add that it was minor and that all would soon be well.

Harrisburg mayor Paul Doutrich found out about TMI from an unlikely source - a caller from Boston at 9:15 Wednesday morning. “He asked me what we were doing about the nuclear emergency,” Doutrich angrily recalled at a Kemeny Commission hearing seven weeks later. “My response was ‘What nuclear emergency?’”.

A taste in the wind

Mary Osborne, living in sight of Three Mile Island's cooling towers six and a half miles to the southwest in her redwood house in Swatara township, remembers hearing about the accident mid-morning. She was sure upon learning the news that it was probably not serious, but she began to wonder if the metallic taste she had noticed earlier when walking her children to the school bus stop was more than a coincidence. To this day countless members of the TMI community can remember such a taste in the air.

One of them was Virginia Southard, a founder of Citizens for a Safe Environment, a small local group that had opposed the licensing of Unit Two. She drove to her office in Union Deposit, a Harrisburg suburb, as usual that day, arriving at 8:30. Around quarter to nine her desk phone rang. A friend living 90 miles west of Harrisburg told her that a mutual acquaintance from Philadelphia (l00 miles to the east) had heard there was a problem at Three Mile Island; her friend asked her to “find out what you can and call me back.” Southard called a reporter from the Harrisburg *Patriot Ledger* who confirmed the story, “but we don't know what's going on down there,” she recalls his telling her. Southard geared for a possible meltdown. She did not stick around. By l0:30 a.m. she had left town. An hour west she remembers a “metallic taste” in her mouth when she stopped for gas. “I never went back to live in Harrisburg,” she recalls today.

Harry Machita, in l979 one of TMI's closest neighbors, did not learn of any difficulties until he returned to his tree-shaded home on Pennsylvania 441, half a mile north of Unit Two, late that afternoon. “I originally thought [TMI] was a good idea - up until the time of the accident,”

Machita now says. By the end of 1979 he had sold his house at a loss and moved 20 miles north.

TMI's neighbors were stunned to see that Walter Cronkite was beginning his CBS Evening News broadcast with a story on Three Mile Island:

> It was the first step in a nuclear nightmare; as far as we know at this hour, no worse than that. But a government official said that a breakdown in an atomic power plant in
>
> Pennsylvania today is probably the worst nuclear accident to date.

As the TMI Community became concerned for its safety, so did the rest of the world. Thus emerged one of the many ironies of the Three Mile Island accident. While the traffic out of Middletown grew with those seeking refuge from the accident and its possible consequences, a counterflow of people rushing into the area started. Technical experts - many called by the utility - and many others came to offer unsolicited advice. Journalists from seemingly every state and dozens of foreign countries came to report on the accident. Disaster experts, sociologists, and various professionals drove in to study the accident and its aftermath. People who just wanted to help in shelters, first aid stations, and other emergency locations flowed in.

"Everybody was here," recalled Anne Trunk, a Middletown resident who served on the President's Commission. A friend who ran a delicatessen "sold a thousand sandwiches in one night. David's Men's Shop nearly ran out of clothes. Everybody thought it was just going to be an overnight stay but it turned out longer." What these visitors were to find was a mix of confusion, uncertainty, and hesitation. Confusion in the plant about what was going on technically. Confusion in the community about the seriousness of the accident and whether it was necessary to leave. Uncertainty from the local Civil Defense Office to the Governor's Mansion about if, when, and how, the population should be moved out. There was hesitation to act in many quarters.

Kevin Molloy, the local civil defense chief, sat by his phone waiting for an evacuation order that never came. Colonel Oran Henderson, head of the state's Emergency Management Agency (PEMA) and the man who would have given that order, was waiting for the go-ahead from the Governor. A holdover from the Schapp Administration, he had barely established rapport with Richard Thornburgh, who had been governor for just two months; by the end of the week, Henderson would be effectively bypassed in emergency decision making for TMI.

Jack Herbein, the utility (then called Metropolitan Edison) vice president for generation called to TMI to act as accident spokesperson, found the pressure of the accident making him hesitant to communicate with the outside world. At a Thursday press conference he snapped at reporters, saying: "I don't know why we need to ...tell you each and every thing that we do specifically." He acknowledged to Lt. Governor Scranton that he had not told the press at an earlier press conference about some radiation releases because "it didn't come up."

Middletown was tense, and the air in central Pennsylvania was so heavy with rumors that a barometer might have gone off scale. No one seemed to know what was happening. Everyone agreed that it was something that had never before been experienced.

Middletown: A portrait

Middletown is truly a middle American town. Tall trees and old brick and frame houses, many sporting ornate gables, line its streets. The commercial center has the usual assortment of stores, coffee shops, and a commuter train station. Dating from 1767, old St. Peter's church, with its handsome stonework facade, sits near the downtown on a plot of land provided by George Fischer, Middletown's founder, for the annual rent of one grain of wheat. A log cabin adorns the middle of the city park, where couples walk hand in hand, and, in summer, where families romp in the community pool.

This colonial era Pennsylvania town, once a bustling port at the junction of the Pennsylvania and Union canals, hardly seemed like the setting for an event that would transform the nuclear power debate - from one of whether nuclear power is safe and reliable to one of how to phase out nuclear power in the most environmentally and economically responsible manner. Yet this is what the accident at Three Mile Island will ultimately be all about.

Middletown has always been sensitive to the importance of energy to its economy. The town's early prominence as a canal port depended on energy supplied by mules pulling boats along the water. For three quarters of a century, electricity has powered the silver-colored trains that shuttled Middletowners to and from other parts of the state. The promise of nuclear power to help keep that electricity flowing was a bright one a generation ago for its citizens.

Nuclear power-generated electricity first flowed in Middletown in the mid-70s, but the plan - the dream, really - of nuclear started much earlier. A sooty coal plant sitting near the town center supplied power to the area and few other than the coal supplier were unhappy with the thought that it would be replaced with a smokeless source of electricity that to virtually everyone's understanding was as safe and reliable as the early morning train to Harrisburg.

A few people questioned the nuclear option. After Unit One went on line in 1974, nuclear power became a literally more visible issue - the cooling towers of Three Mile Island are landmarks visible for miles in the hilly countryside. This visibility, along with the proliferation of nuclear plants across the country and some reported problems with them, meant that the TMI community began to have some second thoughts about the promise of nuclear energy. The people of TMI started to think hard about the tradeoffs implicit in nuclear power - the price in dollars and potential health damage to be paid for this awesome form of energy.

The morning after

As Middletown and the TMI community turned out its lights Wednesday night, an unusual number of its houses were vacant. The town's numbers were depleting as many residents were sleeping away from home. By the weekend over half of the houses within a five-mile radius of Unit Two would be empty.

A scared Middletown awoke to a Thursday that would be filled with releases of radiation into their air and water - officially, all within NRC limits, but considerably more than normal, and probably the heaviest radiation of the accident in a 24-hour period. At 2:10 p.m. a helicopter over TMI-Two detected a burst of radiation measuring 3000 millirems per hour 15 feet over the plant's vent - a level that over a sustained period of time would be extremely serious "created no great concern" at NRC headquarters, according to the Kemeny Commission.

But another release that afternoon, one within NRC limits for radiation releases, did cause considerable consternation. Soon after the accident began Wednesday, Met Ed stopped discharging wastewater from such sources as toilets, showers, laundry facilities, and leakage in the turbine and control and service buildings into the Susquehenna River. Normally this water contains little or no radioactivity, but as a result of the accident, some radioactive gases had contaminated it. The radiation levels, however, were within the limits set by the NRC. By Thursday afternoon, nearly 400,000 gallons of this slightly radioactive water had accumulated and the plant's storage tanks were now close to overflowing. Two NRC officials - Charles Gallina on-site and George Smith at the Regional office [in Philadelphia] - told Met Ed they had no objections to releasing the water so long as it was within NRC specifications. Met Ed notified the Bureau of Radiation Protection and began dumping wastewater. No communities downstream from the plant were informed, nor was the press.

When he heard about this, NRC chairman Thomas Hendrie ordered the dumping stopped. Forty thousand gallons of contaminated water had entered the river by 6:00 p.m. But, after heated negotiations, dumping resumed after midnight. The Pennsylvania Department of Environmental Resources (DER) issued a press release stating that DER "reluctantly agrees that the action must be taken."

To make matters worse that Thursday, NRC's Charles Gallina, at an afternoon press conference with Governor Thornburgh, most incorrectly told reporters that the danger from the accident was "over." By suppertime he and James Higgins, an NRC inspector, had received results of an analysis of a sample of reactor coolant water clearly indicating that damage to Unit Two's reactor core was considerably greater than had been anticipated. It was not until 10:00, however, that Higgins telephoned the governor's office to break the news.

The long weekend

If Wednesday and Thursday were difficult days at TMI, Friday was an impossible one. A kind of apprehension that few had previously felt gripped the community. Early Friday morning churchbells and sirens rang throughout the area, warning of possible new radiation releases. TMI was getting ready for an evacuation. James Floyd was in the control room of Unit Two that morning and around 7:45, in his capacity as Supervisor of Operations for Unit Two, decided that it would be necessary to vent radioactive steam from bubbling superheated water that, in his words, was building up "like a seltzer bottle." To try to control the cooling system, it was necessary to reduce the pressure through venting. But Floyd knew the risk in this action.

By 9:00 Friday morning the Nuclear Regulatory Commission's TMI emergency group - operating out of NRC's Incident Response Center in an office building 110 miles away in suburban Washington, with an open line to TMI - analyzed venting data and came to a singular conclusion: Evacuate. Harold "Doc" Collins, assistant director for emergency preparedness at NRC's Office of State Programs, called Colonel Henderson at the Pennsylvania Emergency Management Agency and passed on the recommendation. Henderson called Lieutenant Governor William Scranton (head of the governor's ad hoc emergency team for TMI), who in turn relayed the recommendation to Gov. Thornburgh. Expecting Thornburgh to order an evacuation, Henderson subsequently called Kevin Molloy, director of Dauphin County's Civil Defense office, telling him to stand by for an evacuation directive.

But it would never come. Governor Thornburgh refused to act on the basis of the Collins phone call. Thornburgh later said, "I did not know Mr. Collins. I never met him or heard of him, and I asked the Lt. Governor to determine who Mr. Collins was and what his authority was for making such a recommendation."

Was Thornburgh proceeding with appropriate caution or was he rolling dice over the wellbeing of the TMI community? To this day it can be argued either way.

By taking time to authenticate the identity of Doc Collins - incredibly, no warning system was in place that provided for a quick and reliable method to authenticate this kind of communication - Thornburgh learned that the evacuation recommendation had been based on a misinterpretation of data. Therefore, the recommendation was withdrawn within an hour of its formulation, and Thornburgh's delay was justified. Instead of an evacuation, he would order an "advisory" for pregnant women and children to go no closer to TMI than five miles.

Yet Thornburgh's hesitation to call for an evacuation would haunt the TMI community. What if the calculation hadn't been wrong? What would that delay have meant to the future physical health of tens of thousands of TMI area residents? Or, even more troubling, was the data interpretation, or misinterpretation, even relevant? Did the very fact that radiation was being vented from the plant mean that it was time to protect people by moving them out? As scientific studies point increasingly to the correlation of exposure to very low levels of radiation

and increased health risks, the gamble that Richard Thornburgh took that Friday morning comes more into question.

On Friday plant personnel also discovered they had a new major problem on their hands: a massive hydrogen bubble had formed in the reactor system. The source of the hydrogen was the elemental breakdown of water - which consists of two parts hydrogen and one part oxygen - caused by a reaction of superheated steam hitting zirconium fuel elements in this irradiated environment. If the hydrogen exploded in the presence of enough oxygen, the long-touted "fact" that nuclear plants could not explode would be yet one more error of history. And a wide geographic area could conceivably be showered with lethal radioactive debris. Until TMI no one seriously contemplated the fact that a nuclear plant could explode. No less respected an authority than the *Encyclopedia Britannica* totally wrote off the possibility of such an explosion:

> Since an atomic bomb and a [nuclear] power reactor are both chain-reacting devices and use the same fuels, there is sometimes a public misapprehension that a reactor may "go off like a bomb." Nothing could be further from the case, since the composition and mode of operation are widely different.

Yet, on Friday, March 30, 1979, even the most die-hard supporters of nuclear power had to acknowledge that a potentially devastating explosion was in the realm of possibility.

Tense debate over a literal life or death issue thus began: Would there be enough oxygen in the system to cause an explosion? And how big would the explosion be? In the TMI plant, at NRC's suburban Washington headquarters, and probably at thousands of locations around the world these questions were pondered. The final, and apparently correct, answer would be no, and the hydrogen bubble would dissolve into the cooling system water. But before the weekend was over, many who had hesitated to leave their homes would be driven out by the hydrogen scare.

The hydrogen bubble was a surprise to everyone. But it should not have been. A September 5, 1969, Atomic Energy Commission report pertaining to permitting TMI construction mentioned the possibility.

The report gave no solution to the potential problem but, incredibly, expressed hope that the utility would find an answer.

It was also on Friday that a new face arrived on the scene - one that would soon be on television screens in tens of millions of living rooms around the world: Harold Denton of the Nuclear Regulatory Commission. Governor Thornburgh, fed up with the conflicting and sometimes abrasive statements of Met Ed and having no one on his staff capable of interpreting technical data pouring out of the plant, asked Denton to come to Harrisburg and be the sole spokesperson for the state on the progress of the accident. Denton arrived in Harrisburg with an overnight bag but would remain for many nights as the accident wore on and finally wound down to a manageable state.

One radioactive element that an explosion at the plant would shower into the atmosphere could be countered by a simple medical technology: radioactive iodine, which could concentrate in the thyroid and cause widespread thyroid abnormalities, including cancers. The simple and benign chemical potassium iodide can be used to prevent this. By ingesting a potassium iodide solution, a person can saturate the thyroid, thus effectively keeping out the radioactive iodine.

According to the Kemeny Commission, no potassium iodide was available, outside of a few laboratories, anywhere in the country that weekend. A frantic effort by the US Department of Health, Education, and Welfare (HEW - now the Department of Health and Human Services) resulted in a joint agreement between Mallinckrodt Chemical Company of St. Louis, Parke-Davis in Detroit, and a bottle-dropper manufacturer in News Jersey) to work around the clock to produce a quarter million one-ounce bottles of potassium iodide. Between Sunday afternoon and the following Wednesday 237,013 bottles were shipped to Harrisburg.

The potassium iodide would never be used, as the situation would calm by Monday. But there was a storm before the calm. People and politicians were frustrated by the lack of accurate information.

As the sun sank low on the horizon that Sunday, the fortunes of the TMI community began to rise; the NRC concluded its original calculations on the bubble danger were in error and that there was no danger of an explosion. By Monday, the immediate danger at TMI had passed. And the very slow process of assessing what had happened and cleaning up the damage began.

It was an accident that, nine years later, the New York Times described as one which "as each piece of evidence has emerged... in retrospect, became more serious." It was an accident so severe that even today has experts wondering what kept the deadly radioactive fuel and reactor components from escaping into the environment - melting material that the utility now acknowledges "flowed like hot olive oil."

Chapter II

The Emergency Winds Down, But The Legacy Starts To Grow

Arthur H. Purcell

Enter the White House

> By the authority vested in me as President by the Constitution of the United States of America, and in order to provide, in accordance with the provisions of the Federal Advisory Committee Act (5 U.S.C. App. 1), an independent forum to investigate and explain the recent accident at the nuclear power facility at Three Mile Island in Pennsylvania, it is hereby ordered:
>
> 1-101. There is established the President's Commission on the Accident at Three Mile Island.
> 1-102. The membership of the Commission shall be composed of not more than twelve persons appointed by the President from among citizens who are not full time officers or employees in the Executive Branch. The President shall designate a Chairman from among the members of the Commission...

On April 11, 1979, two Wednesdays after the accident began, President Carter signed Executive Order 12130, setting up an investigation that would take half a year and ultimately involve hundreds of people. Chaired by (then) Dartmouth President John Kemeny, the Kemeny Commission was only one of several major investigative teams established. Senator Gary Hart of Colorado began a study. The Nuclear Regulatory Commission performed an investigation. The Japanese and the Swedes, among others, set up their own investigations into (then) history's worst commercial nuclear power mishap. But it would be the Kemeny Commission's findings that would stand out as the official word on TMI.

The Kemeny Commission

The first public meeting of the Commission came on May l9th, in Middletown, where dramatic, sometimes wrenching, testimony came rom Middletown citizens on how the accident

had touched their lives: "I'll never forgive nor will I forget what Met Ed did," said one Middletown resident.

"There was a time I would believe the government officials," said another. "But now I don't want to even be asked to believe them… I think the only thing I can afford to do is ask, please, just let it [the TMI plant] shut down." Said a third witness at these hearings: "My faith in Met Ed and the quote `experts' from the NRC was totally shattered." Middletown Mayor Kenneth Reid spoke not only for the TMI community, but for most citizens when he tried to explain to the Commission why the community was so ill-prepared for the accident:

> I don't think the elected officials near that plant took too much interest in it... I was an elected official at that time and I didn't attend one of the public meetings, mainly due to the fact that the plant, Met Ed, said that no accident could ever take place. So we put faith in the Met Ed and NRC and we didn't get involved enough - the people, the elected officials. I think we should have really gotten involved, especially the elected officials, and demanded certain things, but we didn't know what to demand at the time. We were in the dark as far as nuclear energy was concerned and they assured us that no accidents would ever take place and we believed it.

Bruce Lundin, the original staff director of the Kemeny Commission, would subsequently confide in a meeting of senior commission staff how moved he - as someone who had thought of the accident as an essentially technical matter - was by the human dimension of the accident. Lundin, who had envisioned a Commission staff of no more than twenty, pushed for a formal Human Factors portion of the Commission investigation.

That was not, however, to be. For various reasons Lundin would run afoul of some Commissioners and the chief counsel of the Commission. Lundin went on a July 4 break and did not return (although he officially remained a consultant). He was replaced by his deputy, a retired civil servant. The investigation ended up with four investigating teams (Public Health and Safety, Emergency Preparedness and Response, Technical Assessment, and the Public's Right to Information) housed under what was called the Technical Staff, but with a separate legal staff (Office of Chief Counsel) conducting many of its own, and often overlapping, investigations in each area. In addition, a third staff, Office of the Public Information Director, was set up, ostensibly to handle public and press inquiries but in practice to become involved in shaping the flow of information to and within staff investigations.

By the time the Kemeny Commission work was completed, over 200 staff and consultants would be involved.

On May 30th the first hearings were held in Washington by the Commission and this was the Commission's high water mark. The first day of the hearings was telling, in regard to both the potentials and limitations of the President's Commission on the Accident at Three Mile Island.

That afternoon the Commission was to meet its first real test as an investigative body. The only public exposure to date as a group had been the Middletown hearings, during which the Commission would do little more than sit and listen. But now it had to prove its mettle. It was a hot and muggy afternoon. The setting was the New Executive Office Building, a modern red brick high rise across the street from the White House. The tension was high as a nervous Commission and senior staff walked in under the hot press lights to meet its public and its first set of witnesses - Metropolitan Edison executives and the control room operators who had presided over the early hours of the accident.

After some preliminaries and fairly straightforward testimony by the utility executives, the Commission tackled the question of the closed emergency feedwater valves - an error that increased the seriousness of the accident. To this day no one knows who was responsible for closing the valves but Commission probing on that day revealed just how ineptly the utility had handled its internal security pertaining to access to the valves.

Martin Cooper, a Unit Two control room operator, had tested the emergency feedwater valves two days before the accident. At the hearings he steadfastly maintained that he opened the valves when the test procedure was completed. Technical Staff Director Bruce Lundin asked Cooper about the procedure for maintaining records on valve closings:

Lundin: So you verify and sign off on valve open position following completion of the surveillance?

Cooper: Yes, Sir.

Lundin: And that document exists some place today?

Cooper: No, Sir. It is thrown in the trash can.

Lundin: It's just filled out and signed and verified and thrown away?

Cooper: Yes, Sir. That is the way we do our surveillance procedures. Only the data sheets are kept. The actual steps of the procedure, once it is completed, are discarded...

Testimony by John Lionarons, an auxiliary control room operator for Unit Two, revealed that the valves could be operated from three different places: "They can be operated from the

control room; they can be operated from extension controls out in the plant; and they can be operated right at the valve by engaging a clutch and turning the hammer on it."

When asked to elaborate on the "extension controls" method of operating the valves, Lionarons explained that an extension control was situated in a room known as the emergency gear room. "Who has access to this room?" Commissioner Carolyn Lewis asked. The answer startled the commission and was to lead to a suspicion of sabotage - a possibility that cannot be totally discounted even twenty-five years later:

"Everybody," Lionarons stated flatly.

"Anybody in the plant can get in?" asked an incredulous Lewis?

"Just about, within reason," replied Lionarons. "The construction workers, operators, rad chem techs, general people that work in the plant."

Lewis: So anybody could have gone in and out after the 26th into that room and advertently or inadvertently turned these valves off?

Lionarons: That's right.

Bruce Babbitt, another member of the Kemeny Commission, followed up on this testimony, which managed to get sidetracked into a more technical vein after that revelation. Babbitt, governor of Arizona, was the only elected official on the commission, whose membership was heavily weighted toward the academic. John Kemeny, its chair, was a college president. Cora Marrett was a professor of sociology at the University of Wisconsin and Western Michigan University. Carolyn Lewis, formerly a practicing journalist, was at Columbia. Thomas Pigford, a staunch nuclear advocate, hailed from the University of California at Berkeley. Paul Marks, a physician, came from Columbia. Theodore Taylor was a visiting lecturer at Princeton and a consultant. The six non-academics were Russell Peterson, a former governor and at that time president of the National Audubon Society; Harry McPherson, a Washington attorney; Lloyd McBride, International President of the United Steelworkers of America; Anne Trunk, a Middletown housewife, Patrick Haggerty, former chairman of Texas Instruments, and Governor Babbitt.

From Babbitt's careful questioning on the feedwater valves it became clear that improper valve closures had occurred on "at least one or two occasions" before at TMI and that minimal efforts had been made to discover the source of such closures.

In its first public day of investigation, the Commission uncovered some startling evidence - that the TMI plant management and security were so slipshod that they allowed free access to critical plant hardware. Virtually anyone in the plant - including visitors - could enter

the emergency gear room and tamper with equipment. And no uniform record keeping system was in place to identify every person who had come into contact with the valves. These discoveries also brought to light one of the most disturbing facts of life of commercial nuclear power safety - that without exceedingly stringent management and security procedures potentially devastating actions can take place.

At TMI the question of sabotage would soon be raised - did someone with a little knowledge of nuclear power operation purposely close the valves to precipitate an accident?

(A small delegation from the Commission, including the chairman, would subsequently journey across town to meet with FBI Director William Webster to seek help in a possible sabotage investigation. The meeting led nowhere. As a commissioner present at that meeting later reported to the Commission, Webster was unimpressed with the evidence, noting that the FBI would need something more substantial to press an investigation. The matter, at that point, was officially laid to rest. There would be no further action in regard to the sabotage theory.)

The rest of the Commission proceedings that afternoon would be anticlimactic; but as the commissioners and senior staff left the light-drenched room around 5:30 there was a feeling that something definitive had been accomplished. Fatigue mixed with the feeling that the Commission had made a good start to proving its worth.

But this sense of accomplishment was short-lived. Chairman Kemeny called the commission into a closed session immediately after the hearings. “Deputy Chief Counsel wants to speak with you,” Kemeny told the twelve investigators. Stanley Gorinson, a lawyer on leave from the antitrust division of the Justice Department, proceeded to berate them for a job poorly done. You're looking like fools to the public, groping around in a haphazard “fishing expedition” manner, he told the group. “You have to look at this from a lawyer's perspective,” he admonished. Lawyers know how to investigate.

No commissioner murmured disagreement. When the Deputy Chief Counsel had finished, Chairman Kemeny, who had sat nodding affirmatively while Gorinson spoke, then announced that, since the Chief Counsel, Ronald Natalie, had resigned after only a month's service, Gorinson was now Chief Counsel.

The Commission investigation was headed in a new direction in which all considerations - technical, sociological, medical, and others - would be subservient to legal perspectives. Bruce Lundin's dream of a small commission staff that would call upon the services of the two staff lawyers to subpoena needed documents and depose selected witnesses, was reversed. It would now be the other groups - Technical Assessment, Public Health and Safety, Emergency Preparedness and Response, and Public's Right to Information - that would be called on by the Office of Chief Counsel as needed. It was to be a lawyer's investigation. Lundin's planned total staff of about two dozen would soon have 28 lawyers and legal assistants in its midst.

The “lawyer's approach” would pose some problems for the Commission. One was efficiency. Another was public access. While still at the helm of the staff, Bruce Lundin sought to address the numerous public inquiries on the investigation by establishing a citizens advisory committee.

William Millerd, a Jesuit priest and longtime activist with an antinuclear group known as the National Intervenors, was asked to assemble and chair such a committee. When the Chief Counsel got wind of this action, he insisted that the committee not be given any access to Commission undertakings - that its role be limited to answering a questionnaire. When the committee met at the TMI offices on July 24th, there was no business to transact, no agenda to act upon. The result was, as one of the ten committee members put it, “the world's most short-lived advisory committee.” The citizens advisory committee was no more. And a potentially invaluable opportunity for supplementary data and perspectives to be integrated into the investigation process was lost.

The President's Commission on the Accident at Three Mile Island offices were located on the tenth floor of a nondescript building at 2100 M St. NW, less than a mile from the White House. In the northwest corner of the block of offices rented by the commission sat the Public Health and Safety task force. Over the six months the Commission operated a byzantine structure of four subgroups with 23 consultants and 3 fulltime staff. The principal finding of all this, however, was that “the major health effect of the accident appears to have been on the mental health of the people living in the region of Three Mile Island and of the workers at TMI...”

According to the findings of the task force, “no detectable cancers” would be caused by the accident. The “average dose to a person living within five miles of the nuclear plant was calculated to be about ten percent of annual background radiation and probably was less.”

The group calculated a “maximum dose” that was very small and, as noted above, discussed radiation doses in terms of “average” dose. The average, however, is a meaningless concept when it comes to radiation plumes. Talking about an average dose of radiation is akin to assessing a poisoning in the following manner: If twenty people go on a picnic and four get food poisoning and die, the “average” casualty suffered is one fifth death per person.”

Radiation physicist Ernest Sternglass, in work independent of the commission, disregarded the “average dose” concept, and came up with a much more chilling picture of the health effects of TMI radiation. Said Sternglass at a press conference three months after the accident:

> From my own studies and those of Dr. Mancuso, Dr. Gofman, and Dr. Alice Stewart (scientists who have studied low-level radiation effects in different parts of the world), I would estimate that the total cancer rates are probably something like 10 or 100 times greater [than rates around the

> Millstone I nuclear plant in Connecticut], so that I would expect anything from a few hundred to a few thousand extra deaths in this area in the next twenty years as a result of the releases.

Next door to the Public Health and Safety group sat the Emergency Preparedness and Response Task Force. It was the job of this task force to assess the state of planning for the TMI accident, and the quality of the response, and make recommendations for improved preparation and response for future accidents. A major finding of this group was that virtually no specific planning for a TMI accident had been done prior to March 28, 1979. So for many public officials in the TMI community, their major activity *following* the accident was drawing up plans, for the first time, for a possible evacuation.

The principal reason for lack of planning, the task force soon learned, was that the combination of no legal requirement to do so (the NRC only required specific emergency plans for the LPZ, or low population zone, the envelope containing the plant and a few residences) and a pervasive belief that an accident at TMI was a near impossibility meant the TMI community would simply rely on standard emergency plans, written for floods and other natural disasters. An invisible radioactive plume was hard to understand and even harder to plan for. And the products of those few communities that tried sometimes smacked of black humor. The following, which was written as a message to be broadcast publicly in the event of an emergency, is a telling example:

> There is no radiation emergency. Repeat. There is no radiation emergency. We are recommending that all people leave the area for safety purposes only.

This problem was compounded by statistics on evacuations for natural disasters that emphasized the risks of accidents during evacuation. An NRC draft Emergency Ad Hoc Task Force report on the relative risks of human casualties in drills and actual nuclear accident, written before the accident, is illustrative. According to the report, which relied on US Department of transportation figures, "it appears that mortality risk from the evacuation drills (if one considers a 40-year period and assumes an evacuation drill each year with public participation) is greater than the mortality risk from the potential reactor accident with significant offsite consequences."

One of the handful of Kemeny Commission recommendations to be accepted and acted upon by the NRC was that emergency planning outside the LPZ be a requirement for nuclear plant licensing. Yet half a decade later, when Suffolk County, New York and the State of New York refused to develop such plans as a way to block licensing of the Shoreham plant on Long Island (both bodies, after study, had concluded that it would be impossible to successfully evacuate the Shoreham area in the event of a mishap), the NRC very seriously considered striking that requirement to speed licensing of Shoreham. Shoreham was never licensed and the

state of New York and the Long Island Lighting Company, owner of Shoreham agreed on a plan to close the unused facility.

The next office down the hall at Kemeny Commission headquarters was that of the Technical Assessment Task Force. Staffed primarily by military and NASA personnel on detachment from their regular duties, this group had what was probably the most complex but least emotional and controversial assignment of the investigation - to pinpoint the technical causes of the accident. And this group would soon learn that there were many.

Investigation showed that the TMI plant was replete with technical design problems and the accident was characterized by numerous technical difficulties - from a poorly designed control room to malfunctioning equipment to decisions made on misinterpreted technical data. The pilot operated relief valve (PORV) sticking open was one prominent example; and investigation
revealed that March 28th was not the first time it had stuck in the open position at TMI and other plants.

The PORV had failed a dozen times previously. Yet no one had considered the implications of a stuck PORV on the safety of a nuclear plant. Data display and processing technology in the TMI control room were hopelessly out-of-date. At one point during the early part of the accident the data printer was running more than an hour behind schedule.

The operators had no quick way, as the accident grew, to determine a critical piece of data - the boiling point of the water in the cooling system, which depended on the system pressure. On your kitchen stove water (at sea level) boils at 212 degrees, but under pressure the temperature is much higher. An exchange between Commissioner Taylor and TMI control operator, at the May 30th hearing, on this point well illustrated how poorly equipped the operators were:

> Taylor: During the accident, did you have any steam tables handy in the control room that you could look at to correlate saturation temperature [and] pressure?
>
> Zewe: I have a set of steam tables in my office in my desk and I believe that there were steam tables available at the operator's desk, but not readily available.
>
> Taylor: Were you or anyone else that you know of asking anyone for numbers that would require looking things up in the steam table? Were you trying to correlate things? Were you asking questions and not getting answers because there weren't steam tables available? Or did you send someone off to try to get the steam tables?

> Zewe: I did not send anyone off for steam tables or try to correlate that. We were reacting to what we had and trying to put together and formulate what we were going to do.

The inadequate technical training of the TMI control room operators was clearly brought out by the investigation. Despite periodic simulator training at a Babcock and Wilcox facility in Lynchburg, Virginia, the men responsible for running Unit Two on March 28, 1979, were ill prepared to face the supposedly nearly impossible Class IX accident that began on their watch.

Further down the hall at 2100 M St. sat a group - The Public's Right to Information Task Force - that examined the information flow of the accident. The main question it addressed could be stated as: Was the public - in Middletown and beyond - served well by the media? Did the public get the kind of information it needed to respond to the accident?

What this group found was that "Neither Met Ed nor the NRC had specific plans for providing accident information to the public and the news media." The flow of critical information to the public had to be channeled on an improvised basis and the flow was far from smooth. Even the Governor's effort to provide a single spokesperson - the NRC's Harold Denton - had its limitations. As the task force noted:

> This agreement limited the number of sources available to the news media and while it brought some order out of the chaos in public information, it raised two problems. First, information on off-site radiation releases was not centralized in any source so that it would be readily available to the news media and the public; and second, the plan provided no specific public information role for the utility.

A controversy that crops up in any story of national prominence is whether the media attempts to shape a story instead of just report on it. Whether for a presidential election or a nuclear accident, media reporting will be accused of bias or purposeful inflaming of issues. This was certainly the case during the TMI accident, where so many citizens were dependent on the media newspapers, radio, and especially television - for guidance on whether to stay or go, whether the accident would endanger their lives.

For the men and women of the utility, media coverage would prove an embittering experience. An exchange between the control room operators and the Kemeny Commission was illustrative:

> Commissioner Trunk: I'm glad you weren't scared, because I was.
>
> Craig Faust: Well, you heard the news media.

Edward Frederick: The only time we felt safe was when we were in the plant. To turn on the TV was enough to panic anybody.

TMI neighbor Harry Machita remembers how the media affected his own sense of the accident. Seeing Walter Cronkite's helicopter land in a field near his house was an intimidating experience, and probably was instrumental in his moving his family out of the area the weekend of the accident.

The Kemeny Commission found considerable fault with the way the NRC conducted business prior to the accident. Particularly disturbing was the governing structure of the NRC - a five-member commission, nominally run by a chairman but, in fact, a five-headed body. "A debate society is no way to run the ship" was Bruce Babbitt's assessment of why the NRC should be run by a single administrator answerable to a public oversight committee. Twenty-five years after the TMI accident, however, the five-headed body of political appointees continues to collectively hold the reins of the country's nuclear watchdog agency.

The Commission spoke of a mindset as one of the real culprits at TMI - a public frame of mind that "[A]fter many years of operation of nuclear plants, with no evidence that any member of the general public has been hurt, the belief that nuclear power plants are sufficiently safe grew into a conviction...The commission is convinced that this attitude must be changed to one that says nuclear power is by its very nature potentially dangerous, and, therefore, one must continually question whether the safeguards in place are sufficient to prevent major accidents."

"Human Error"

If the Commission as an assembled body had one major failing it was its nondecision on the subject of a nuclear power moratorium. The major question that its public was asking, beyond "What happened at TMI?" was "Should there be a nuclear power moratorium until it can be demonstrated that the severe problems brought out by TMI can be solved?"

The Commission debated, off and on throughout that hot summer, whether it should stick its collective neck out and call for a halt in nuclear power development, making official a condition that the U.S. marketplace was by that time imposing; not since the year before had any new domestic order been placed for a nuclear plant.

At least eight commissioners spoke, at various points, in favor of a moratorium. But when a formal vote finally came, no more than six would say "aye;" the motion was defeated on a tie. With that vote the President's Commission on the Accident at Three Mile Island probably passed up its one chance to make a definitive statement to the American public that the hour had come to start thinking about phasing out the national nuclear experiment.

The White House response to the accident at Three Mile Island - establishing a high level body to investigate - unwittingly proved how vulnerable we are to human foibles. The

Commission probably did as good a job as it could have under the circumstances. Yet its work was far from perfect. From missed chances to misguided acts of the staff, human imperfections limited the Commission's usefulness. Seven years later investigations of Chernobyl would suffer from the same problem. Probes of other nuclear mishaps will likely have similar limitations. But for something as serious, complex and potentially hazardous as nuclear power generation, these limitations are costs that society cannot afford.

Twenty-five Years of Conflicting Data

From its onset, the accident at Three Mile Island has entailed a set of conflicts and seeming anomalies. What has made TMI such a difficult event to understand and assess is that, from the outset, there have been two very different schools of thought on the degree of its severity and its long-term significance. To strong proponents of nuclear power, TMI proved that "the system held," that despite grave human errors, no major accident took place. The possibility, to this group, that the TMI accident was a much larger one than originally thought, is not worth considering.

To others, TMI was and is a major accident proving that nuclear technology is fatally vulnerable to human mistakes. Both sides have data to support their contentions.

And the discrepancy in this data is particularly disturbing when it comes to the major reason for worrying about TMI - health effects of the accident. Officially, i.e., to people and institutions like the Kemeny Commission or the Pennsylvania Health Department, the health effects were minimal. The Kemeny Commission found mental stress as the only important health impact. The TMI Health Fund, funded by a large accident-related settlement paid by Met Ed, concluded in 1990 that, despite a cancer rate in the accident area nearly double the national average, the TMI accident could not be blamed.

A number of reports of possible accident-related health problems were dismissed by official sources. When it was learned, e.g., that in the period following the accident women in the sizable Amish community to the south and east of TMI had an unusual number of thyroid problems, a leading state health official reportedly attributed this to a statistical fluctuation.

Yet, as nuclear critics like Marjorie Aamodt pointed out, this could also be due to the fact that the Amish community did not learn of the accident until days after it began and that women, working in the fields, took no precautions by staying indoors.

Local activists

Marjorie and Norman Aamodt have delved into the health issue in great detail as their concern over the accident's impact grew. The Aamodts have spent considerable amounts of their time and savings studying the accident and challenging many of the official findings. They investigated the health issue in great detail as their concern over the accident's impact grew. They reasoned that, since the TMI plant is well below the highest point of land in the area - in

fact, sitting on a flat island in the middle of the Susquehenna River, it is in the lowest terrain in the area - it was possible that locations downwind from radiation plumes might have been subjected to sizeable accumulated doses of radiation.

Studying wind patterns from the early part of the accident, the Aamodts ultimately identified three areas, sitting on hillsides and downwind from the accident, where over a long period after the accident cancer death rates were about seven times what would have been expected according to established state statistics. Try as they might, however, the Aamodts were unable to convince people like the head of the Pennsylvania Health Department that the cancer death rate acceleration was related to what happened in Middletown after March 28, 1979.

Some medical experts, however, did take note. Carl Johnson, a former Jefferson County, Colorado, health official who surveyed people in the Rocky Flats area complaining of symptoms that TMI community members would later report, told a reporter in 1987: "I was impressed that the incidence of cancer deaths was so high. There is a very, very high proportion of cancer deaths to all deaths here, far more than one would expect under normal circumstances. The numbers indicate that the emissions that came down in those areas may have been far higher than originally believed." Johnson felt that radiation from TMI One, which had operated four years longer than Unit Two, might also be a contributing cause.

This type of data, usually referred to as anecdotal (because it is gathered informally through telling of "anecdotes" instead of through formal, scientifically designed surveys), abounds for TMI.

Eileen Smith, a journalist who lived in Middletown for a time after the accident, put together anecdotes by talking to hundreds of people. "When you talked to people you found lots of independent confirmation," she says. The "metallic taste," burning and tingling of skin, and stillness in the air that included stoppage of all bird singing have been widely reported around the time of the accident, according to Smith's research. "I started out as a nonbeliever," says Smith, "but I was mistaken."

Anecdotal evidence pointing to a possible correlation between the TMI accident and radiation damage is not limited to humans. The plant mutation damage uncovered by people like Mary Osborne of Swatara Township and Jane Lee of Edders convinced at least one respected botanist that there was enough radiation released at TMI to be very harmful. Dr. James Gunkel, a retired Rutgers University botanist and former Brookhaven National Laboratory scientist, whose field of specialty was radiation-induced plant damage, stated the following in a 1984 affidavit:

> I have carefully examined a few specimens of common plants collected shortly after the accident at TMI and compared them with specimens collected more recently. The current abnormalities are probably carried forward by induced chromosomal aberrations.

> There were a number of anomalies entirely comparable to those induced by ionizing radiation... Most of the stem abnormalities described in the literature and in my own experience are induced by relatively high doses of X or Gamma radiation extended over a period of usually two to three months. Notable exceptions, however, are similar responses to beta exposure from radioisotopes Phosphorous-32, Zinc-65, and Calcium 45 for only 24 hours.
>
> In other words it would have been possible for the types of plant abnormalities observed to have been induced by radioactive fallout on March 29, 1979...

The Nuclear Regulatory Commission, however, saw no correlation between plant or animal mutations in the TMI area and the accident. A 1980 report (NUREG 0738) concluded that:

> While in some instances not enough data were available for a detailed evaluation to be made, none of the reported problems could be linked to TMI and no general pattern of effects could be seen.

After TMI, widespread reports of abnormal farm animal births and stillborns began to surface. Robert Weber, a veterinarian based in Mechanicsburg (northwest of Middletown) reported a sizable increase in the number of caesarian sections he performed on pigs after TMI - from one or two a year (Caesareans are only performed in the case of severe birthing difficulties of the sow) to a few a week.

The NUREG 0738 report concluded, however, that "many of the reported livestock problems were probably the result of nutritional deficiencies. In her interviews with TMI community members, Eileen Smith has heard many stories of deformed litters being born shortly after TMI, with one woman living within five miles of the plant having a cat whose entire litter of twelve was stillborn.

Jane Lee, who lived in a farmhouse across the river and less than four miles from TMI conducted over a thousand interviews with fellow farmers and others after the accident. She found plant and livestock deformities, along with human cancers and other afflictions, which seem to date from the accident.

Harry Machita, who lived down the road from TMI, began having thyroid problems after TMI. A number of TMI community residents claim that the accident started skin problems that long plagued them.

It is difficult to sort out the full meaning of anecdotal medical and biological evidence, since so many variables are involved. Has, for example, the accident made people more prone to report symptoms or disorders that they ordinarily would ignore or attribute to other causes? Could these phenomena plausibly be attributed to coincidence? Or, as Norman Aamodt maintains, are they manifestations of what he calls "natural dosimeters?" Or are people simply exaggerating or remembering things that did not happen?

The answers to these questions will probably never be known, though on the last point the evidence points to a negative answer; too many independent confirmations of evidence have been made to attribute these stories to falsehoods or power of suggestion. At least some of the anecdotal evidence seems worth further investigation. The Aamodt findings, and their reasoning that led to them, cannot be totally ignored. And the list of anecdotal findings that seem to indicate
a pattern of irregularities that were totally missed or ignored by official investigations of the TMI accident continued to grow for years after the accident. As Mary Osborne has explained: "People tell me they never mentioned these things before because they simply didn't think they were important. Slowly they have come forth."

The symptoms reported after the accident are not unique to TMI. Members of the "Atomic Veterans" - a group of people who participated in early atomic bomb activities - report a "metallic taste" after atomic bomb blasts. And the following anecdote well illustrates the problem of what to do with anecdotal data: it is at first glance, irrelevant yet, at the same time it seems to provide some independent confirmation from a long distance of two of the most commonly appearing symptoms after the accident - skin inflammation and thyroid irregularities:

A day after the accident a plume was known to pass over the small town where a woman named Jean Merigeault lived. She began to have severe skin rash on her face. Lasting for several weeks, the rash, which she had not had previously, is now a recurring one. Around the same time a friend began to have problems with her thyroid after years of remission of a previous condition. The accident in question was Chernobyl and Jean Merigeault lives in central France. Yet in that country, where a radiation plume from the very serious Chernobyl accident was known to have passed, and around TMI, where many feel that sizable plumes did, in fact, develop, similar symptoms were reported by reliable individuals. The coincidence is striking.

Continuing Controversy

The debate over the impact of the TMI accident on health continued into the 1990s and 2000s. In January 1997 Steve Wing and colleagues from the School of Public Health at the University of North Carolina, Chapel Hill, published in *Environmental Health Perspectives* "A Reevaluation of Cancer Incidence Near the Three Mile Island Nuclear Plant: The Collision of Evidence and Assumptions." Reexamining data gathered from 1975 to 1985 on residents within 10 miles of the plant, they found that "Accident doses were positively associated with cancer incidence. Associations were largest for leukemia, intermediate for lung cancer, and smallest for

all cancers combined." Errors in methodology including failure to take into account weather patterns and indefensible assumptions about the received dosage created problems in earlier reports, they stated.

In October 2002 Evelyn Talbott and colleagues from the Graduate School of Public Health at the University of Pittsburgh published in Environmental Health Perspectives, "Long Term Follow-Up of the Residents of the Three Mile Island accident Area: 1979-1998." Talbott summed up the findings in an interview with BBC News (November 1, 2002), "The study… confirms our earlier analysis that radioactivity released during the nuclear accident at Three Mile Island does not appear to have caused an overall increase in cancer deaths among residents [within a five mile radius of the plant] over the follow-up period, 1979 to 1998." She did, however, admit that the authors found higher death rates from lymphatic and blood cancers that might merit further study. The study was supported by a grant from the Three Mile Island Public Health Fund. Eric Epstein, Chairman of Three Mile Island Alert, Inc., charges that Talbott did not take plume pathways into consideration and points out that in 1986 TMI-Alert and area political representatives unsuccessfully petitioned a federal court to remove the administrators of the Public Health Fund, whom they charged with nepotism and poor communication with the community.

Chapter III

The 1940s and 1950s: The Birth of the Nuclear Industry

The history of the nuclear industry begins in the early twentieth century, with the pivotal discoveries that would make uranium fission possible. It would, however, be about three decades before these discoveries began to be applied to energy theories. In the 1930s theoretical scientists came to the realization that the atomic chain reaction could release enormous energy. This understanding dawned as the world plunged headlong into the Second World War. Spurred on by rumors of German achievements, US scientists constructed the world's first nuclear reactor in secret at the University of Chicago. There, in December 1942, they initiated the first self-sustaining nuclear chain reaction. The reaction was allowed to operate for only 4.5 minutes, but it produced a little heat, an indication that the atom would eventually be put to civilian as well as to military use [Rhodes 1986, p. 440].

Military beginnings

Overcoming many technical hurdles, the United States, through its Manhattan Project, produced sufficient plutonium for a bomb at Hanford, Washington. The plutonium was secretly transported to a laboratory at Los Alamos (30 miles northwest of Santa Fe, New Mexico). There assembling and triggering details were worked out under the direction of Robert J. Oppenheimer. July 16, 1945, the first experimental bomb was detonated at the Alamogordo Air Base (210 miles south of Los Alamos). Meanwhile, scientists at Oak Ridge, Tennessee, were enriching uranium.

The nuclear era was launched publicly in the closing weeks of World War II, when President Harry Truman authorized the bombing of Hiroshima and Nagasaki. August 6, 1945, the B-29 "Enola Gay" dropped a single uranium bomb on Hiroshima. "Heat rays with

temperatures of more than 3000 degrees Celsius caused primary burn injuries within two miles of the hypocenter. About 130,000 of Hiroshima's 350,000 people would die" [Wyden 1984, p. 255]. August 9 a plutonium bomb was dropped on Nagasaki.

For many of us living at that time the news was incomprehensible; a fundamentally new form of warfare was now before us that banished any glamour that war could have still retained. Entire cities - and cities with innocent people and not armies - could be annihilated. The blankets of conventional bombs that reduced Dresden and Tokyo to ruins were no longer needed; it now took a single bomb in one awful moment.

The two atomic blasts filled the world with wonder and some United States citizens with remorse - after an initial joy over ending a war. An uneasiness settled over all. Prudent people knew the secret could not be kept for long, and there would be nuclear proliferation when and where there was a critical mass of technical people. Some of the scientists who had initially urged the development of nuclear weapons had petitioned Roosevelt's Secretary of War Henry Stimson to display the bomb's power but not to drop it on a population center; this would have spared innocent Japanese from horrible burns and lingering death from radiation sickness.

The US press helped American citizens forget the horror by writing of the civilian applications of the atom. The pronouncements of prominent Americans was grist to their mill. The Chancellor of the University of Chicago, Robert M. Hutchins, for instance, predicted that "Heat will be so plentiful that it will even be used to melt snow as it falls… A very few individuals working a few hours a day at very easy tasks in the central atomic power plant will provide all the heat, light, and power required by the community and these utilities will be so cheap that their cost can hardly be reckoned" [quoted in Ford 1986, p. 30].

Nevertheless, testimony in Congress on the possibility and benefits of the "civilian atom" was inconclusive. Congress passed an Atomic Energy Act in 1946, but the act's main purpose was the protection of the US monopoly on nuclear weapons and technology. The Act provided for civilian control of nuclear weapons but mentioned nuclear energy only in passing [Ford 1986, pp. 31-32].

The Act established a five-member Atomic Energy Commission (AEC), appointed by the President to replace, the Manhattan Project; and gave oversight of the Commission to a group of eighteen members of Congress, nine from each House, called the Joint Committee on Atomic Energy (JCAE). The AEC was to own the nation's nuclear infrastructure, including the weapons laboratories and all reactors, whatever their function. It was also to own all nuclear materials.

The preamble of the Atomic Energy Act stated loftily, "it is hereby declared to be the policy of the people of the United States, that, subject at all times to the paramount objective of assuring the common defense and security, the development and utilization of atomic energy shall, as far as practicable, be directed toward improving the public welfare, increasing the standard of living, strengthening free competition in private enterprise, and promoting world peace."

Nevertheless, in its early years, the AEC concentrated on building a nuclear weapons stockpile. At the close of World War II the nuclear weapons production network consisted largely of small, scattered, privately-owned facilities. These facilities were under "almost no central management" [Ford 1986, p. 32]. Turning the network into a "complex of large, centralized, government-owned production facilities" geared to mass producing weapons required enormous effort [US Dept. of Energy 1997, p. 1].

In 1946 the stockpile had nine nuclear weapons; in 1947, thirteen; and in 1948, fifty. In 1949 the Soviet Union detonated its first atomic device; in 1950 the Korean War broke out. Also in 1950 President Truman placed development of a thermonuclear (hydrogen) bomb on a crash basis [Cochran et al. 1984, pp. 6-7]. The Truman administration regarded expanding the nuclear arsenal and diversifying the types of weapons as crucial. Carroll Wilson, the first general manager of the AEC, stated, "All of the other priorities were higher than nuclear power" [quoted in Ford 1986, p. 33].

Among the AEC's higher priorities was nuclear propulsion. In 1947 the Atomic Energy Commission and the Navy had begun working together in the Naval Reactors program on a reactor for a new military use, propulsion of submarines and surface ships. Under the leadership of Admiral Hyman Rickover, the Naval Reactors program cooperated with the commercial firm Westinghouse to develop a pressurized water submarine reactor (PWR). The prototype had its initial power run in May 1953 at what was then the National Reactor Testing Station (NRTS) in Idaho. In January 1954, the Navy launched the *Nautilus*, the first submarine propelled by nuclear energy.

Another priority was obtaining fissile material for atomic bombs. Uranium, which can be enriched to produce fissile material, occurs naturally; but at the end of World War II, uranium was in short supply. The United States, in fact, had to depend largely on foreign sources, because major ore deposits in the western United States had not yet been discovered [Cochran et al. 1987, p. 2].

Plutonium, unlike uranium, exists only in traces in the natural world, but it is produced when uranium absorbs neutrons during a chain reaction. Every reactor fueled by uranium produces some plutonium, as neutron absorption transforms a portion of the uranium-238 in the fuel into plutonium-239. However, fast neutron (breeder) reactors were believed to be particularly adept at producing plutonium. (A breeder is fueled with plutonium mixed with natural or depleted uranium or with enriched uranium. The fuel core is surrounded by a cover of uranium-238 that, under the bombardment of neutrons, is turned into plutonium.) The AEC was therefore interested in using breeders to create fissile material.

The Commission authorized Argonne National Laboratory to build the first liquid metal breeder reactor at the NRTS. It went critical in August 1951. December 20, 1951, EBR-1 produced the world's first electricity from a nuclear reactor. It did not demonstrate plutonium

breeding for the first time (creating more fissile material than it consumed as fuel) until June 4, 1953 [Cochran et al. 1987, pp. 1-2, 31].

The push for a nuclear power industry

By 1953 the AEC had decided to separate military plutonium production from the development of civilian power [Makhijani and Saleska 1996, p. 58]. It wanted to move ahead quickly with a civilian reactor program, in part to obtain a propaganda advantage over the Soviet Union. Although the United States was engaged in a nuclear arms race with the Soviets and although the Soviets were developing a civilian program, the administration planned to present the US nuclear program as a symbol of peace in contrast to what it described as the militaristic Soviet program. To this end, it wanted the United States to be the first nation to embark on large-scale nuclear generation of electricity. As the JCAE chairman Sterling Cole stated in 1953, "The possibility that Russia might actually demonstrate her 'peaceful' intentions in the field of atomic energy while we are still concentrating on atomic weapons could be a major blow to our position in the world. It could even disrupt the continued operation of our own weapon plants by stimulating friendly countries to cut off vital uranium they now sell us" [quoted in Makhijani and Saleska 1996, p. 48].

The choice of a design for the civilian reactor was a matter of short-term expediency. The AEC had been working on various types of reactors. According to a DOE history, an AEC classified report delivered to the Joint Committee in February 1954 "included reasonably candid evaluations of the status of each [reactor design] concept. The pressurized water reactor, which was already proving its feasibility in the submarine program, seemed most likely to be successful in the short term - by the end of 1957, but it offered a poor long-term prospect of producing economic nuclear power" [quoted in Makhijani and Saleska 1996, p. 60]. Desirous of quick success, the AEC turned to the PWR.

(Pressurized Water Reactors [PWRs] like Boiling Water Reactors [BWRs] are what are called Light Water Reactors [LWRs], that is they are cooled and moderated [their neutrons slowed down] by light water [ordinary water]. Their fuel is low-enriched uranium. The main difference between PWRs and BWRs is that PWRs have three separate water circuits; BWRs have only two. Thus in a PWR the water that is turned into steam to drive an electricity-generating turbine does not come into direct contact with the fuel; in a BWR it does.)

The choice of the PWR would put the United States into the position of being able to control nuclear power development overseas. At the time, the United States was the only nation with a free-market economy that had the capacity to enrich uranium. Light water reactors require enriched uranium. Therefore nations wanting to follow in the footsteps of the United States would have to obtain enriched uranium from the United States on US terms.

In May 1953, the Pentagon cancelled a project to build a nuclear-powered aircraft carrier. The JCAE gave the work of developing an electricity-generating PWR to the team that had worked on the aircraft carrier. Still under the leadership of the very competent Rickover, Naval

Reactors (the joint Navy/AEC organization) contracted with Westinghouse and then, in late 1954, with the private utility, Duquesne Light Company [Makhijani and Saleska 1996, pp. 61, 63]. The three entities constructed a 90 MW PWR (Megawattage for reactors is given throughout in terms of electrical energy and net power) at Shippingport, Pennsylvania, on the Ohio River. The reactor was owned and largely financed by the US government, but was operated by Duquesne Light Company, which contributed to the cost of development [Federation of American Scientists 2003].

The United States successfully tested a thermonuclear device for the first time on November 1, 1952; the Soviet Union detonated a thermonuclear device in August 1953 [Rhodes 1986, pp. 777-78]. In this context, in December 1953, General Eisenhower gave his influential Atoms for Peace speech in the United Nations. Attempting to refashion the image of the United States from that of atomic "bully" to that of "advocate" for peace, Eisenhower offered other nations technical assistance in developing nuclear programs for peaceful purposes and suggested that an international organization be set up to receive and distribute nuclear materials to this end.

Nuclear technology rapidly became a tool of American foreign policy; by 1956 some 25 agreements for nuclear materials, technical facilities, and nuclear training, had been negotiated between the United States and other countries [Gyorgy 1979, p. 9]. In 1957, as suggested in Eisenhower's speech, an International Atomic Energy Agency (IAEA) was established to try to ensure that nuclear materials were not diverted to non-peaceful uses. That agency continues functioning to this day under the auspices of the United Nations.

Meanwhile, to encourage the nuclear generation of electricity within the United States itself, Congress had passed a revision of the Atomic Energy Act in August 1954. The revision authorized private ownership of reactors and fissionable material and private patent rights for the production and utilization of fissionable material. Fuel cycle facilities, except enrichment plants, could also be privately owned.

The Act contained a fatal flaw. The Commission was to serve as both proponent and regulator of nuclear power. Another weakness was that the language was couched in terms of economic development and contained no requirements to help protect public safety, as for example, the siting of reactors in remote areas. The combination of industrial willingness and massive governmental appropriation ($14 billion by 1956) was to launch a nuclear industry from scratch [Gyorgy 1979, p. 10].

In 1955 the AEC announced a Power Reactor Demonstration Program, under which it would assist in the design and construction of commercial plants. Commonwealth Edison in 1955 ordered a General Electric boiling water reactor (BWR) for a site in Dresden, Illinois; and Consolidated Edison, a PWR for Indian Point, New York. The following year the Yankee Atomic Electric Company signed a contract for a Westinghouse PWR to be constructed in Rowe, Massachusetts. These small reactors were built with the help of government subsidies or other supporting involvement [Makhijani and Saleska 1996, p. 68].

Also in the mid-1950s, Detroit Edison decided to construct the Enrico Fermi breeder reactor as a showcase for the AEC's Demonstration Program. The Enrico Fermi would use as fuel an alloy of uranium enriched to 25.6% uranium 235 [Finon 1989, p. 75].

A 30 MW nuclear power plant at Vallecitos, California, jointly built by Pacific Gas and Electric and General Electric Company, became the first privately owned reactor to produce substantial amounts of electricity. Vallecitos was connected to the grid in October 1957. The 90 MW Shippingport Station began operating in December 1957. The Dresden and Rowe plants went on line in 1960. (Dresden was licensed to operate in 1959, but had to be shut down for a short time almost immediately after startup because of technical difficulties.) Indian Point was connected to the grid in 1962.

In the mid-1950s the AEC mounted a major propaganda campaign. The Commission's show "Atoms for Peace" was viewed by 2.2 million people, and exhibits were targeted to American schools and to audiences in other countries. *Our Friend the Atom*, a book published by Walt Disney, was immensely popular. A subsequent television production addressed only the upbeat aspects of nuclear power. "Atomic science has borne many fruits… the harnessing of the atom's power is only the spectacular end result… we can indeed look upon the atom as our friend."

The first AEC chairman, David Lilienthal, would later write that scientists and administrators must go to great lengths to try to establish a non-military use for atomic power. Gordon Dean, the Chairman of the AEC from 1950-53, commented that "atomic power can become a powerful and forceful influence towards the maintenance of world peace." The nuclear establishment would, in fact, use the nuclear power program as a means of helping to justify the continuation of nuclear research and the continued production and development of nuclear weapons.

Health

The health effects of radiation were first discussed in connection with nuclear weapons. Later, as the nuclear electricity program grew, the impact of radiation from nuclear reactors and other civilian facilities became an issue.

That exposure to radiation could cause serious illness and death was obvious to the general public from accounts of the bombing of Hiroshima and Nagasaki. However, the American authorities were fond of describing the impact of radiation in terms of gamma radiation, which they compared to x-rays. The phenomenon affected the body from the outside and in an instant. The public was told not to worry about the effects of nuclear testing, even when atmospheric tests began in Nevada in mid-1950.

However, residents living downwind of the tests - and downwind could mean thousands of miles away - soon became distrustful. Thousands of sheep unexpectedly died in southern Utah. In 1953 heavy rains brought to earth fallout materials that contaminated the reservoir in

Troy, New York. Cases of leukemia began to appear at abnormally high rates among the residents of certain towns in Arizona, Nevada, and Utah.

In 1955, two scientists at the University of Colorado Medical Center became so alarmed at increases in radiation in Colorado that they went public with the truth. "The upsurge in radioactivity measured here within a matter of hours has become appreciable," Dr. Ray R. Lanier and Theodore Puck announced. Readings of gamma ray levels did not tell the whole story. "The trouble with airborne radioactive dust is that we breathe it into the lungs, where it may lodge in direct contact with living tissue." This is not the same as having radioactive particles land on skin or clothing from which they can be brushed off. Moreover, there is no "safe minimum 'exposure' below which danger to individuals or their unborn descendants disappears. Or at least we do not know what it is" [quoted in Wasserman, pp. 92-93].

In short order the impact of fallout became a subject of national controversy, with representatives of the AEC generally continuing to declare its harmlessness and independent scientists including the Nobel prize winners Linus Pauling and Hermann Muller expounding the opposite point of view. Governor Adlai Stevenson made "radioactive fallout" a campaign issue in his unsuccessful challenge to President Eisenhower in 1956. The National Committee for a Sane Nuclear Policy (SANE) was founded in l956 and within a year had 25,000 members opposed to the tests [Wasserman 1982, pp. 58-101].

Also in 1956 the British physician and researcher Dr. Alice Stewart presented the first solid evidence that low-levels of radiation can cause cancer. "We were able to demonstrate that the flicker from one X-ray photograph to a fetus could initiate a cancer. This was a tiny fraction of the amount considered safe," she wrote [quoted in Wasserman 1982, p. 95].

Safety

The immediate health effects of weapons and weapons testing were not the only warning signals of nuclear power's fallibility. An experimental test reactor in Chalk River, Ontario, endured a partial fuel meltdown and released a million gallons of radioactive water inside the reactor in December, 1952. In November, 1955, almost half the core of the EBR-1 reactor at the National Reactor Testing Station in Idaho melted. Had it turned into a critical mass, it might have exploded [Gyorgy 1979, p. 117]. The reactor was undergoing experiments with reduced coolant [Cochran et al. 1987, p. 31], but misshapen fuel rods and reactor error made possible the accident [Gyorgy 1979, p. 118].

A fire at Windscale Pile No. 1 in England in October 1957 resulted in the release of 20,000 curies of radioactive iodine and contaminated milk for more than 200 square miles. The reactor was permanently shut down. Chalk River was again the site of an accident in 1958, when a fuel element in a reactor lacked coolant. The radioactivity was apparently contained in the building [Makhijahni and Saleska 1996, p. 121], but a lengthy cleanup was necessary. Then in July 1959 the 7.5 MWe Santa Susana Sodium Reactor Experimental (SRE) at Santa Susana, California, experienced a partial core meltdown, releasing contamination. The reactor had been

built by Southern California Edison and Atomics International [California Energy Commission 2003].

Critics were demanding that governments address the accident probabilities of nuclear plants. In 1956, at the request of the Joint Committee, the AEC asked its Brookhaven National Laboratory to study the possible results of a major nuclear accident. The conclusion appeared in March 1957 in what is known by its AEC publication number as WASH-740 - "Theoretical Possibilities and Consequences of Major Accidents in Large Nuclear Power Plants." The meltdown of a 200 MW (relatively small) plant 30 miles from a population center would result in 3400 deaths and 43,000 injuries. Damage to property could be as high as $7 billion [Ford 1986, p. 45]. The report also found that 150,000 square miles of land could be contaminated. People could be killed up to 15 miles from the plant and injured up to 45 miles away [Gyorgy 1979, p. 111].

The AEC never fully recognized the WASH-740 study. Granted, the assumption that half of the fuel core's radioactive materials would be released erred on the high side (more likely 10%). Nevertheless, power plants five times larger than the hypothetical plant have since been constructed, and a number of plants are nearer to major population centers. As a result, the study underestimated dangers.

Utilities were certainly not willing or able to handle accidents of the size predicted by even WASH-740. Thus in the year this report became known, Congress quickly enacted a law requiring the government (i.e., taxpayers) to bear some of the liability if such a catastrophe ever occurs. This legislation, the Anderson Indemnity Act of 1957 guaranteed $500 million in federal money for accident liability and required a pool of $60 million from the utility insurers. And, very importantly, it limited the total liability of a nuclear accident to the sum of these figures. The act has since been periodically renewed with different dollar figures but the same purpose.

A paradox thus emerged: the nuclear industry - then, as now - claimed that its operations were perfectly safe. Yet it lobbied hard for Federal legislation to cap liability for an accident. For
more than four decades nuclear opponents have asked a question that the industry is unable to answer, i.e., if nuclear power is so safe, why do you need the Price Anderson Act?

Chapter IV

The 1960s: The Bandwagon Market

During the infancy of nuclear energy, the industry benefited from the federal government's determination to advance the peacetime development of nuclear power. No other energy source has ever enjoyed such befriending. As Leo Yochum of the Westinghouse Power Systems Company said during the TMI crisis - "I just don't understand this talk about nuclear being dead. The market is going to return. After all, there is a nuclear imperative in this country."

Nevertheless, at the beginning of the sixties, nuclear power was what nuclear critic and writer Daniel Ford calls a "small, government-subsidized sideshow." [Ford 1986, p. 58]. Federal support was fading, with the Bureau of the Budget considering decreases in construction subsidies. *Science* magazine in April, 1962, asked what had happened to the glamour of atomic power. It commented that the space program had replaced atomic energy as the center of interest during these early years of the Kennedy Administration. From the utility standpoint, coal was still the major fuel for electricity generation. Coal was in plentiful supply, and, because of steam generation efficiencies, the cost of electricity generated from coal was dropping. Even former AEC Chairman Lilienthal regarded commercial nuclear power as a "flop" and "not to be taken seriously" [quoted in Ford 1986, p. 59].

Despite federal assistance, the nuclear plants that had been constructed were more expensive than originally anticipated. For example, Indian Point had cost $125 million instead of

a planned $55 million. Nuclear power did not look to utilities to be a sound investment. By 1961 only Shippingport and Dresden had been licensed to operate (licenses were not granted until reactors had run for some time); and twelve small prototype reactors were under construction [Ford 1986, pp. 58-59].

Matters became so bad that President Kennedy asked Glenn Seaborg, the new AEC Chairman, to take a long, hard look at nuclear power. The result was *Civilian Nuclear Power: A Report to the President 1962*, which called for vigorous development of nuclear energy.

Seaborg, a strong advocate of commercial nuclear power, predicted that major economic breakthroughs would occur to lower construction costs. He took the figures for his report from the estimates of reactor manufacturers. They had been for some time advocating the construction of larger reactors, which would result in economies of scale. Seaborg predicted that by the year 2000 half of the electricity consumed in the United States would be generated by nuclear power. Unfortunately he did not demand a reappraisal of the suitability of Westinghouse and General Electric reactor designs for large-scale commercial nuclear power plants nor a review of the long list of safety "unknowns" that had been identified during the previous decade.

Seaborg's report helped convince the utilities that larger nuclear power plants would be a very good buy. In December 1963 Jersey Control Power and Light Company purchased, without federal subsidies, a 5l5 MW BWR to be built on Oyster Creek, New Jersey. The 515 MW capacity was more than double that of Dresden 1 (200 MW) and Yankee-Rowe (175 MW) and almost double that of Indian Point (265 MW). General Electric sold the reactor below cost, in order to demonstrate that nuclear power could compete economically with coal. GE lost an estimated $30 million on the contract, but the agreement was the turning point in the nuclear manufacturers' struggle to gain acceptance by utilities [Ford 1986, pp. 62-63].

General Electric and Westinghouse sold a total of thirteen reactors at cost. They and other reactor manufacturers also began offering fixed price contracts (subject to increase only due to inflation) and turnkey contracts (under which the companies provided complete ready-to-operate power plants rather than simply reactors). [Makhijani and Saleska 1996, pp. 69-70]. The price cutting by industry substituted for the previous government subsidies (except for the Price Anderson Act, still in effect today).

By the mid-1960s the following, in addition to Jersey Control Power and Light, had applied to the AEC for licenses for new nuclear power plants: Commonwealth Edison of Chicago to build Dresden-2, (ordered in 1965) 794 MW, almost four times the size of Dresden-1; Consolidated Edison of New York to build Indian Point-2, (1965) 994 MW, almost six times the size of Indian Point-1; and the Tennessee Valley Authority to construct Browns Ferry (ordered in 1966) - two reactors, each 1065 MW, bigger than all the others [Ford 1986, p. 88]. The orders then came thick and fast. "About 45 percent of the capacity of all nuclear generation ever brought on line in the United States was ordered during this 'Bandwagon Market' of the mid-1960s" [Makhijani and Saleska 1996, p. 70]. "By April 1968, about 100 reactors were operable,

under construction, or being ordered" [Gyorgy 1979, p. 14]. Two of these were Three Mile Island-1, ordered in 1966, and Three Mile Island-2, ordered in 1967.

The push to nuclear power in the last half of the 1960s had more to do with profits than with whether nuclear energy was actually cleaner or better. From 1960 to 1969, electricity use almost doubled (688 billion kilowatt hours in 1960; 1314 billion kilowatt hours in 1969) [US DOE, Energy Information Administration 2003]. Furthermore, capital was available for new plants. The prices of utility stocks were climbing rapidly. Earnings were healthy, the costs of producing electricity were declining, and demand was growing because of increased advertising by utilities. Regulatory agencies were slow to cut rates, and utilities were including costs for developing nuclear plants in the rate base - and swimming in money.

Fuel accounted for significantly more of the costs of running fossil-fired plants than it did for nuclear plants. Interest rates were low. For long-term bonds they were between 4.0% and 4.5% from 1960 through 1965. They then began creeping up, but had only reached 6.18% in 1968 and 7.03% in 1969 [Officer 2003]. Thus utilities could afford to borrow to build new plants, and by the decade's end a nuclear plant was a more attractive investment than other types of generating facilities. Banks, insurance companies and other capital-laden groups got the word. *Electric World*, a trade journal, predicted in its September 15, 1972, issue, that by 1985, 45% of the electricity produced would be generated by nuclear power. A 1968 Arthur D. Little report estimated that electricity generated by a 1000 MW PWR would cost about a half cent per kilowatt hour - a figure far lower than was actually ever attained.

Health

Finally in August 1963, the United States, USSR, and United Kingdom signed a limited atmospheric test ban treaty. Atmospheric testing by France and China continued. A comprehensive test ban treaty was not to be signed until 1996.

In 1963 Glenn Seaborg, then Chairman of the Atomic Energy Commission (AEC), asked respected scientist Dr. John Gofman to study at its Lawrence Livermore Laboratory the effects of "man-made environmental radioactivity" [quoted in Wasserman 1982 , p. 209]. He and his associate Dr. Arthur Tamplin, came out with their findings in 1969. They asked that the AEC's maximum permissible radiation dose to the general population be reduced from 170 millirads a year to 17 millirads a year. If every individual were exposed from birth to 170 millirads a year, deaths from cancer would increase by 32,000 a year and from genetic defects by 150,000 to 1,500,000 [Gyorgy 1979, p. 18]. The AEC retaliated against the scientists causing both eventually to resign [Wasserman 1982, p. 211].

In the 1960s concerned citizens and scientists organized small opposition groups at the sites of planned nuclear reactors and began to intervene in licensing hearings. The best known instance of opposition was that against the Enrico Fermi fast breeder reactor, which Detroit Edison undertook to construct in the mid 1950s. The reactor was to be cooled with liquid sodium, which rendered the plant extremely dangerous. Sodium explodes on contact with

moisture and burns on contact with air. Its location increased the danger, as it was to be in Monroe, only forty miles south of Detroit. The AEC's Advisory Committee on Reactor Safeguards (ACRS) advised against the plant in 1956, but the AEC's director Glenn Seaborg overruled the ACRS and allowed construction to begin. In 1961, the United Auto Workers intervened to stop construction, but the Supreme Court ruled that the AEC was acting within its authority when it approved the Fermi plant because the AEC had broad regulatory powers [Gyorgy 1979, p. 15].

Accidents

On January 3, 196l (in the waning weeks of the Eisenhower Administration) when an experimental reactor at the AEC's Idaho Falls testing ground, SL-I (Stationery Low Power Reactor), was shut down for inspection and routine maintenance, something went wrong. An explosion occurred, and the massive radiation caused the near-instant death of three members of the crew. In an internal AEC memo a decade later, Stephen Hanauer, a nuclear safety advisor, said that SL-I was no "accident" but that one of the operators had been bent on murder-suicide; the disturbed person allegedly caused a runaway chain reaction by withdrawing the central control rod [Ford 1986, p. 204]. This insight was not comforting, because it illustrated the fact that sabotage of other nuclear plants was a very real possibility.

October 5, 1966, the Enrico Fermi Fast Breeder Reactor, about the dangers of which the AEC had been thoroughly warned, was the scene of a partial meltdown. Fortunately the plant was undergoing startup procedures and operating at only 15% of full power. Operators were able to shut it down successfully. It took one and a half years to work out the cause of the accident. A piece of metal had broken off at the bottom of the reactor vessel and blocked the coolant flow. The plant was closed for good in 1972 and was later decommissioned. The accident became the subject of John Fuller's book *We Almost Lost Detroit* (1975).

In the summer of 1964, the AEC secretly began work on an update of WASH-740 that was to examine the risk posed by the large reactors then being considered. Scientists at the Brookhaven National Laboratory were asked to conduct the technical analysis on which conclusions would be based. They found that a major accident at a 1000 MW reactor could kill as many as 45,000 people, injure 100,000, and cause property damage as high as $280 billion. The AEC never released the study or even admitted that it existed. The study came to light in 1973 when an attorney, Mike Cherry, threatened to sue the AEC under the Freedom of Information Act [Gyorgy 1979, p.112; Ford 1986, pp. 67-69].

Meanwhile, the AEC's Advisory Committee on Reactor Safeguards (ACRS) was worried about the escalation in size of the planned nuclear reactors, especially about Indian Point-2, which was some 25 miles north of New York City. Indian Point II could not explode. Its fuel is too dilute for that. However, as in other BWRs and PWRs, the fuel could overheat and melt, causing a major release of radioactivity. The AEC's 1964-65 update of Wash-740 discussed this danger, but the AEC was withholding the details of this study from the ACRS.

What the ACRS was able to learn of the study was not reassuring. The director of the update, in a meeting with the ACRS, admitted that the study showed that melting of the uranium core of a large reactor could cause the fuel not only to penetrate the reactor vessel but also to melt through the concrete beneath the vessel into the ground (the China Syndrome). ACRS realized that possible failures that could lead to the China Syndrome included the shearing of the bolts that held the top of the reactor in place, a malfunction of the control rods, and a breakdown in the emergency core-cooling system (ECCS).

The ACRS repeatedly asked the AEC to take steps to cope with the possibility of the China Syndrome. The steps that the Committee advocated included additional tests of the ECCS systems, which had been tacked onto plant designs at the last minute, and a "core-catcher" to stop melted fuel from penetrating the ground. Like the AEC itself, however, the ACRS did not make its safety concerns public for fear of bringing about a "moratorium" on reactor construction.

Over the years, the ACRS asked the AEC to require a variety of safety measures. The AEC seldom acted on them, because the Commission did not want the industry to have to go to the expense of implementing them [Ford 1986, pp. 87-95].

Waste

By the 1960s nuclear waste was becoming an obvious problem. The AEC had no "coherent, comprehensive program for managing radioactive wastes. If the AEC had a policy with regard to waste disposal, it was one of deferring a solution to the indefinite future. As a result, waste management was effected through a series of short-term 'technical fixes,' many of which proved inadequate virtually upon implementation" [Lipschutz 1980, p. 139]. Unfortunately, after the AEC was abolished, AEC staff who worked for ERDA and then for the DOE tended to carry over the AEC's disinterest in waste to these agencies.

The operation of nuclear reactors and the production of reactor fuel, the dismantling of the reactors and fuel production facilities, and nuclear weapons production all create radioactive waste. In the United States today radioactive waste is classified as:

--high-level wastes (irradiated fuel and the liquids produced by chemically treating the fuel-reprocessing);

-- uranium mill tailings (the voluminous solid waste resulting from the milling and other processing of uranium ore to concentrate the uranium). Since the uranium ore mined in the United States contains less than 1% uranium by weight, essentially all of the ore that is removed from the ground and is treated ends up as tailings. The tailings typically consist of a slurry containing ground-up, sand- and clay-size, waste-rock particles, most of the uranium-daughter nuclides, and hazardous chemical residues. Releasing gamma radiation and radon among other substances, they can contaminate the water, air, and soil;

--transuranic wastes (wastes containing more than 100 nanocuries of transuranic

nuclides per gram of material (10 nanocuries per gram prior to 1984) [Makhijani and Saleska 1996, pp.17-18]. In the United States, where commercial fuel has seldom been reprocessed, nearly all transuranic waste is of military origin;

--low-level waste (all wastes not included in the above categories - for example reactor parts and cleaning materials). Approximately 99% of all commercial low-level waste comes from nuclear power reactors. This waste originates in the escape of radioactive materials from the fuel into the reactor's cooling water and in the bombardment by neutrons of the metals that make up the reactor. If one leaves out of account the irradiated metal reactor components, the products of cleansing the cooling water - ion-exchange resins, concentrated liquids, and filter sludges and cartridges - account for most of the radioactivity in low-level waste from power reactors. Trash such as mops and booties accounts for the majority of the volume but only about 15% of the radioactivity.

Mill tailings were heaped up beside the mills that produced them. Until 1970, transuranic waste was buried alongside ordinary low-level waste. From then until the opening of the Waste Isolation Pilot Project in 1999, the transuranic waste was simply packaged and stored [Lipschutz 1980, p. 34]. Irradiated fuel, which is millions of times more radioactive than fresh fuel, was cooled and then stored in reactor pools.

AEC facilities were reprocessing (dissolving in acid) military irradiated fuel to recover the plutonium and unused uranium. In 1956 the AEC announced that it was willing to share reprocessing technology with private companies. However, no commercial reprocessing plant opened until ten years later. The West Valley plant in New York started operating in 1966. The management was a subsidiary of W.R. Grace called Nuclear Fuel Services (NFS). After NSF's sale to Getty Oil in 1969, the plant continued to reprocess fuel until 1972. A controversial report by Dr. Ernest Sternglass of the University of Pittsburgh Medical School stated that infant mortality rose 54% in Cattaraugus County in the year after the reprocessing plant began operation [Gyorgy 1979, p. 51].

Low-level commercial waste was initially dumped at sea, the fate also of low-level military waste. Burial grounds were located off the Farallon Islands near San Francisco, off Boston Harbor, and off the Delaware coast [Lipschutz 1980, p. 125]. After complaints from commercial waste generators about the cost of sea dumping, the AEC cleared the way for commercial waste to be buried on land. For a short time the Commission allowed the waste to go to the federal facilities that received military waste. Then government-licensed, privately operated dumping grounds took over.

Six commercial radioactive landfills began operating in the United States before 1979. The first opened in 1962 near Beatty, Nevada; the last in 1971 at Barnwell, South Carolina. The others were at Maxey Flats, Kentucky; West Valley, New York; Sheffield, Illinois; and Beatty, Nevada. In 1965 a site opened within DOE's Hanford reservation, 25 miles from Richmond, Washington. DOE leases the site to the state of Washington. The company US Ecology operates it.

Chapter V

The 1970s: The Decade of "Three Mile Island"

By the early 1970s, the tightening noose of economics was already curbing power plant siting, design and construction. Northeast Utilities' Millstone Point-2 plant had been designed to cost $186 million; it actually cost $418 million. Calvert Cliffs 1 was to have cost $272 million; it cost $429 million when completed in 1975. Portland General Electric's Trojan plant was to have cost $239 million but ended up with a price tag of $465 million as the result of a 98% overrun. Tennessee Valley Authority's (TVA's) Browns Ferry 1 & 2 had a walloping 168% cost overrun on an initial investment of $247 million. The outlook for the construction costs of uncompleted plants was even dimmer.

A major reason for the rise in construction costs was an increase in safety requirements. Between 1955 and 1965, the growth in the size of nuclear plants gave rise to economies of scale - less structural steel and concrete were needed per megawatt in 1965 than in 1955. However, a 1200 MW reactor built in the mid 1970s required the same amount of steel and concrete per megawatt as a 200 to 300 MW electric plant in 1960. The reason was tighter requirements for plant licensing in the mid-1970s [Bupp and Derian 1978, pp. 156-57].

Other factors contributing to the rise in construction costs were an end to the industry's offers of "at cost" contracts, and a continuing rise in interest rates. Long-term bonds paid 8.73% in 1978 and 9.63% in 1979. Since nuclear plants were capital intensive, i.e., the costs of construction were high in comparison to the cost of fuel, higher interest rates put nuclear energy at a disadvantage in comparison with coal and gas.

Utilities continued to order nuclear plants in the 1970s - for instance, Arkansas Nuclear One-2 [sic] (1970), Byron-1 (1971), Callaway-1 (1973) - but they did so at a declining pace. No nuclear reactors were ordered in the United States after 1978, and many of those that had been ordered were eventually cancelled, some after construction had begun.

The AEC conceived a Liquid Metal Fast Breeder Reactor Project (LMFBR) in 1969. In 1972 President Nixon announced the federal government's commitment to building the LMFBR along the Clinch River near Oak Ridge, Tennessee. In 1973 the AEC signed an agreement with TVA and a consortium of more than 700 public and private utilities to build the Clinch River Breeder Reactor as a cooperative demonstration project [Taxpayers 1982] with the AEC having the lead responsibility for the project [Breeder 1980, p. 21]. The ceiling on the private utilities' share of the costs was frozen at $257 million - only 7.2% of projected cost as of 1982. The cost escalated wildly; and, safety considerations aside, left the plant wide open to criticism [Taxpayers 1982; Breeder 1980, p. 21].

Health

In 1970 the National Academy of Sciences, at the request of the Secretary of Health, Education and Welfare, created the Advisory Committee on the Biological Effects of Ionizing Radiation (the BEIR Committee). The Committee was to investigate Gofman's and Tamplin's data and the AEC radiation standards. It released its report in 1972. Although the Committee did not arrive at the same statistics as Gofman and Tamplin, it did find that exposure standards were "unnecessarily high" and that radiation standards had been seriously underestimated. By 1971, the AEC had itself proposed a reduction in routine emission standards at a power plant boundary to 5 millirems per person per year. Emissions were to be kept "as low as practicable," but what did that mean? [Gyorgy 1979, p. 19].

In 2003 the BEIR is still in existence, and the question of how much exposure to radioactivity is permissible for nuclear workers and for the general public is still controversial. Because of the complexity of the issue, we shall not attempt to track it into the 2000s in this report.

Safety

Three Mile Island's accident was not a bolt out of the blue. In fact, a whole series of accidents has plagued the nuclear industry. The Public Citizen group in Washington, D.C. has recorded a year by year count. During the 1970s some of the more serious precursors to TMI included:

--(June, 1970) Dresden II in Morris, Illinois. The reactor was out of control for two hours, and iodine-137 was released into the containment vessel. While the reactor was subsequently shut down for repairs, technicians discovered problems with the emergency core cooling system;

--(November, 1971) Monticello in Monticello, Minnesota. Some 50,000 gallons of radioactive waste water spilled into the Mississippi River from the Monticello plant. A portion entered St. Paul's domestic water system;

--(March, 1975) Browns Ferry in Decatur, Alabama. A workman started a fire that burned control cables and caused $150 million in damage. Investigators found that the plant came near a meltdown;

--(June, 1975) Zion, in Zion, Illinois. Fifteen thousand gallons of radioactive water leaked into the reactor containment building;

-- (July, 1976) Vermont Yankee in Vernon, Vermont. Eighty-three thousand gallons of water contaminated with radioactive tritium spilled into the Connecticut River (the second of three similar spills) [Gyorgy 1979, pp. 119-120].

In 1973 the AEC was forced to admit that it had covered up the results of the study updating WASH-740. This was just one of many revelations that forced a reorganization of the agency.

Reorganization

Congress felt compelled to eliminate the conflict of interest in the Atomic Energy Act that made the AEC both a proponent and a regulator of nuclear power. In 1974 it therefore divided the highly criticized AEC into the Energy Research and Development Administration (ERDA) responsible for reactor development, military applications, and research including the development of non-nuclear energy, and the Nuclear Regulatory Commission (NRC) responsible for licensing and regulatory functions. This separation of missions was appealing on the surface - but was imperfect. The new NRC was mostly composed of AEC personnel who carried nuclear advocacy over to the new agency.

Two years later, during the last year of the Ford Administration, the powerful Congressional Joint Committee on Atomic Energy (JCAE) was dissolved and the members scattered among other congressional committees.

In 1977 during the Carter Administration, Congress created the Department of Energy (DOE), which absorbed ERDA along with the Federal Power Commission and programs from several other departments. The DOE was to promote a variety of sources of energy, but, as *No Nukes* sums up, "a nuclear bias remained, reflected in budget priorities and staff selection" [Gyorgy 1979, p. 24]. The NRC retained its role as regulatory agency but has never freed itself from a tendency to support and even promote the nuclear industry.

Waste

During the 1970s three of the low-level waste sites that had opened in the 1960s were shut down: West Valley, Maxey Flats, and Sheffield. All three had experienced problems: "water infiltration into trenches, subsidence of earthen trench covers, and erosion." Radioactivity had migrated from all three sites and expensive remediation was underway [Resnikoff 1987, p. 33]. (A fourth site, the US Ecology site at Beatty, Nevada, closed at the end of 1992. It was located in a drier area than the three sites that closed earlier. Nevertheless, tritium has been found to be leaking from that site [Okologie Institut 2003; Sierra Club 2003].

The 25-acre West Valley commercial waste disposal site in New York was adjacent to the West Valley nuclear fuel reprocessing facility, as was a 7-acre area licensed by the Nuclear Regulatory Commission (NRC). The reprocessing plant leased the 3345-acre site on which it was located from the state of New York. The only "licensing" of the commercial area was a waiver that the New York Health Department granted against the department's general prohibition of land burial.

At the NRC site 528,000 curies (139,000 cubic feet) of highly radioactive waste plus a half ton of irradiated fuel elements were buried in unlined holes. From them, radioactive kerosene and tributyl phosphate gradually seeped through the silty soil towards the feeder of Buttermilk Creek.

At the commercial area, about 750,000 curies (2.3 million cubic feet) of waste was buried in unlined trenches. The 25 acres were located in part in what was formerly known as Spidler's Swamp. Water seeping through the clay covers of the burial trenches allowed water levels within the trenches to rise, as the covers were more permeable than the sides and bottoms of the trenches. In 1987 seepage levels in one trench reached a point at which the water had to be pumped down to prevent the cap that covered the trench from breaking through. This trench (trench 14) was equipped with an eight-foot clay cover and was the best constructed of the burial trenches. The commercial landfill began receiving materials in 1963 and ceased operation in 1975 [Resnikoff 1987, pp. 37-40].

The 300-acre Maxey Flats low-level waste disposal site started operation in 1963 in northeastern Kentucky. By the mid-1970s the site was known to have radioactive leaks. The state of Kentucky and the US Environmental Protection Agency (EPA) found that highly carcinogenic plutonium had moved hundreds of feet from the burial site and was appearing in surface soils and drainage streams. The area has heavy rainfall. As trench caps sank, about 2 million gallons of water per year began entering the trenches. An evaporator that could process 1.2 million gallons per year was installed. Not only did it not process all the seepage, but tritium (radioactive hydrogen) was released in the steam. The site was closed to commerce in 1977. The state had purchased site and leased it to the operator Nuclear Engineering Company (NECO, now US Ecology). When the site closed, the state bought the lease rights from NECO and began maintaining the site itself.

A third "low-level" radioactive waste disposal site was opened on 20 acres near Sheffield in northern Illinois in 1967. It was owned by the Illinois Department of Nuclear Safety, but, like

Maxey Flats, was operated by NECO. By 1978 the company had buried there 60,000 curies of fission products, 55 kilograms of plutonium and uranium-235, and 600,000 pounds of uranium-238 and thorium. The site's capacity was exhausted. The state attorney general opposed expansion of the site, in part because it was found to be leaking tritium. The site was officially closed in 1979. By 1984, an underground stream contaminated with tritium was found to be moving east at a rate of 2000 to 3000 feet a year. Trench caps had severely deteriorated, and needed to be constantly maintained [Resnikoff 1987, pp. 35-37].

A reprocessing plant built by General Electric at Morris, Illinois, to handle irradiated fuel, was to have begun operation in 1972, but it never worked. GE had made the mistake of abandoning the standard reprocessing method for a new system, which "tended to clog up." The company abandoned the plant, unused. Another reprocessing plant, constructed by Allied-General Nuclear Services (a joint venture by Allied Chemical Company and General Atomic) at Barnwell, South Carolina, was completed in 1975. The NRC decided that the liquid waste would have to be solidified at the reprocessing site before being shipped elsewhere. As of 1976 waste-solidification facilities would have cost $500 to $650 million. (The plant itself cost $250 million.) Allied General would have liked the federal government to purchase the plant and lease it back to the company, but the government refused to do so. Therefore this plant has also never operated [Lipschutz 1980, pp. 123-24].

President Jimmy Carter announced in April 1977 that the United States would "defer indefinitely all civilian processing of spent nuclear fuel" [quoted in Gyorgy 1979, p. 24]. Carter did so to reduce the risk that nuclear weapons material would be stolen. The reprocessing plant would have supplied plutonium to fuel the proposed Clinch River Breeder Reactor.

Growing opposition

In the 1970s groups opposing nuclear power became larger and more aggressive. Citizen interveners backed by their scientific and legal experts experienced small victories. According to *No Nukes*, they managed to make some plants safer and to mitigate environmental impacts by such means as adding cooling towers. They also delayed the granting of licenses. The AEC stated that the average time for issuing construction permits went from 10 months in 1967 to over 20 months in 1971, because of new environmental legislation and the intervenors [Gyorgy 1979, p. 20].

The National Environmental Policy Act, which went into effect January 1, 1970, was one of their tools, but the AEC had to be forced to comply with the Act. The Commission refused to consider thermal pollution from the two proposed Calvert Cliff reactors on Chesapeake Bay, on the basis that it had only to consider non-radiological issues, in this case, thermal pollution, in regard to plants that had applied for their licenses before March 4, 1971. A group of intervenors took the AEC to court, and in July the US Court of Appeals in DC decided in their favor. The decision meant that 63 license applications involving 91 plants and 5 operating licenses were open to environmental review. The AEC did not appeal to the Supreme Court, but the victory in court did not prevent completion of any plants.

Furthermore, the AEC fought back. In March, 1972, it urged Congress to amend the Atomic Energy Act to permit "emergency operation" of the nuclear power plants now held up by environmental challenges. Procedures were to be streamlined and the role of intervenors would be severely restricted. Though this counterattack was not successful, it was to mark the first of a number of subsequent administration attempts to weaken NEPA.

Meanwhile the Clinch River Breeder Reactor planned for Tennessee became the target of a national antinuclear campaign. In 1971 the Scientists Institute for Public Information (SIPI) went to court to force the AEC to prepare an environmental impact statement for the breeder program. In 1973 a federal Court of Appeals decided in its favor. The suit had delayed by more than a year the licensing procedure and had drawn national attention to the breeder. Antinuclear activists and others across the country criticized the breeder on grounds that it would contribute to nuclear proliferation, was excessively expensive, and might cause a catastrophic accident. The disappearance of the AEC and then of the JCAE deprived the breeder of support. In 1977 President Jimmy Carter decided to stop the breeder project as well as to affirm a decision by President Ford not to allow the reprocessing plant at Barnwell to operate. Congress continued to fund the Clinch River breeder project until 1983 when it voted to put a halt to it. On this issue, the antinuclear movement had shown its power.

To academic and legal opposition to nuclear power had by now been added marches and blockades with accompanying arrests. The growing number of “anti-nuke” groups was developing a sophisticated network of information and support. These local and regional organizations were beginning to unite and form national coalitions. The National Intervenors, directed by Irene Dickensen, was active in licensing hearings across the country, particularly in Michigan, New York, and Washington, D.C. A national convention of antinuclear activists was held during the summer of 1978 at the University of Louisville. The sporadic protests and citizen interventions of the early 1970s had turned into a chorus of vocal opposition by the end of the decade, when the partial melt down of the fuel at Three Mile Island threw into question the viability of the entire “civilian” nuclear industry.

Chapter VI

The 1980s: Tackling Radioactive Waste

The fifth decade of nuclear power began with the gloom of the TMI accident and a determined and growing opposition to nuclear power hanging over the industry. American utilities were not in the position of ten years before, when they saw indefinite expansion ahead of them. Running scared, they were not only refraining from ordering nuclear plants but were canceling nuclear plants that they had already ordered. In the 1980s, 61 plants were cancelled, some of them after construction had been started. A group of Harvard economists concluded early in the decade that "commercial nuclear power in the U.S. has reached a dead end."

But the 1980s were the Reagan years, and the incoming Administration stressed reductions in energy conservation measures and alternative programs and continued relatively generous support for nuclear energy. The rash of cancellations and nuclear plant deferments was blamed by that administration on over regulation, but there were a number of other causes of nuclear's decline:

--falling growth in the demand for electricity;
--cost overruns;

--a change in the relationship between the cost of coal and the cost of nuclear power;
--a heightened awareness of the economic and safety risks involved;
--and uncertainties about how to dispose of nuclear waste [Environmental 1982].

Growth rates

The growth rate in consumption of electricity dropped with new efficiencies in appliances and other conservation measures initiated during the two oil crises of the 1970s. Energy consumption per dollar of gross domestic product (GD) declined from 18.97 British thermal units in 1970 to 16.0 in 1980 and 12.61 in 1990 [US DOE 2003, Table 1.5]. Adding to the energy efficiency factor, were the results of the over-expansion of the energy industry in earlier decades when stocks were high and investments appeared to have a good return. Furthermore, coal and oil plants with relatively high fuel costs but low capital costs could afford to run well below capacity; but nuclear plants with high capital costs and relatively cheap fuel costs could not. According to the annual DOE statistics the growth rate in US electricity use, 10.1% in 1959 and 9.2% in 1969, had given way to 2.69% in 1979 [US DOE 2003, Table 8.5]. Furthermore, nuclear energy, which had raised such high hopes actually dropped from 12.5% of total energy generation in 1978 to 11.3% in 1979 and 11.0% in 1980.

Cost overruns

A variety of factors such as technical and management problems, construction delays and higher wages and interest rates caused cost overruns to average three or four times and even reach ten times original estimates. Licensing requirements had increased in the mid-1970s After TMI the NRC added yet more variety of safety and equipment requirements that demanded additional time and money. Between the late 1960s and the 1980s, average construction time increased from six to twelve years. *Forbes Magazine* (February 11, 1985) noted that plant costs ranged from $932 a kilowatt for Duke Power's McGuire 2 to $5192 a kilowatt for the Shoreham operation. Forbes said the disparities were "so great as to make a prima facie case for mismanagement in the first degree."

At its start the industry was insulated by easy money and it did not pay much attention to costs. The NRC seemed to have forgotten about the economic costs of regulations; the contractors, designers and construction management with their cost-plus contracts never raised the question of cost-effectiveness; the utilities always trusted that rate commissions would provide the revenue to get them out of their troubles; and equipment manufacturers never seemed concerned about making cheaper reactors. Rate commissions did not call the inflating costs of nuclear plants into question soon enough.

Lower cost of coal

During the 1970s coal overtook nuclear in economics (not taking future decommissioning costs of nuclear plants into account) and held a decisive advantage by the early 1980s. In February, 1981, the Atomic Industrial Forum (AIF) published a survey showing that, among the plants coming on line during the preceding six years, coal plants were cheaper than nuclear plants. For instance, the three 1978 nuclear plants had an average generating cost of 2.5 cents per kilowatt hour versus 2.0 cents for the two coal plants.

Safety factors

One TMI lesson was that the overly optimistic low-probability-of-accident forecasts were seriously in error. The high priests of nuclear safety had been wrong - and the people were beginning to realize it. Safety was now a major issue that regulators and the industry could not ignore. At an NRC Authorization Hearing in the US House of Representatives, April 17, 1985, the NRC itself estimated that there was a 45% chance of a meltdown in the next two decades. That same year it launched its nuclear power plant aging research program (NPAR).

Indeed the industry was growing older. Over half the operating reactors were at least a decade old by 1990 and a few led by Yankee Rowe were by then nearing their thirty-year possible retirement age. Some age-related problems were developing - and more disturbing, signs of premature age were appearing. With age, it was assumed, there would be costly down time. By 1981 the down time of nuclear plants was averaging 40%, with half of that time taken up by repairs alone [Environmental 1982]. Piping, electric wiring, pumps and valves, and reactor vessels needed more attention. A 1987 NRC study performed by the Idaho National Engineering Laboratory showed that 31% of plant failures overall were due to aging. Of pump failures alone, 77-84% were due to aging. The cause of 87-90% of check valve failures in the service water system was also aging [Aging 1988].

The NRC found that welds, tubes and the vessels themselves in older reactors, especially PWRs, could become brittle as a result of high pressure, rapid cooling and the constant bombardment of neutrons. The conditions were reminiscent of the situation when hot liquids are poured into a glass vessel. The problem was given special attention during the Rancho Seco reactor shutdown in 1978, when the pressure vessel was put under severe stress due to a sudden influx of cooling water. Experts agree that had the Rancho Seco reactor been more than three years old, it would have cracked. In 1982 the NRC required 44 nuclear plants to test their reactor vessels, but did not make special distinctions by manufacturer.

The degrading of the steam generators (cracking and thinning of tubes) at PWR and other nuclear plants also became a major problem. Generally the leaks were slow and were cleaned up with little notice. However the Robert E. Ginna power plant rupture in 1982 allowed 11,000 gallons of coolant to spill on the plant floor, and some of the radioactive water turned to steam and escaped into the atmosphere. Steam generator replacement costs could run higher than $160 million a reactor and may result in heavy worker radiation exposure. In July, 1987, another tube rupture occurred at the North Anna, Virginia plant.

In December 1986 Virginia Power's Surry plant underwent a severe accident involving pipe thinning - a pipe burst killing four workers. The conduit pipe was supposed to have lasted 40 years but broke in its thirteenth year. Water running through the pipe at high pressure and speed had corroded it eventually causing it to fail. Subsequent thinning was reported at the Wolf Creek (Kansas) and Trojan (Oregon) nuclear power plants [Aging 1988].

Waste disposal

The waste disposal problem was beginning to grow acute in the early 1980s. Localities with nuclear installations wanted places (preferably distant ones) for disposal of radioactive wastes. The same mentality pervaded state governments. By 1982 seven states - California, Connecticut, Maine, Maryland, Montana, Oregon, and Wisconsin - had enacted laws banning nuclear plant construction until radioactive waste problems were solved.

High-level waste (Irradiated Fuel)

Most people were starting to realize that waste problems would grow in seriousness as irradiated fuel rods continued to pile up at nuclear power plants. Plant pools were becoming so full of spent rods that they were rapidly exceeding design capacity. In the event of a blackout, caused for example, by an earthquake cooling, water at on-site waste pools would soon overheat, leading to a catastrophic release of radioactivity.

In 1982 Congress passed the Nuclear Waste Policy Act, directing the US Department of Energy to find a site for, build, and operate an underground repository for high-level waste. In 1983 DOE chose nine locations in six states for consideration as potential repository sites. The agency studied the nine sites and reported on the results in 1985. Based on DOE's report, President Reagan chose three sites for more intensive study: Hanford, Washington; Deaf Smith County, Texas; and Yucca Mountain, Nevada. In 1987 Congress amended the Nuclear Waste Policy Act and instructed DOE to study only Yucca Mountain. The amended Act states that if Yucca Mountain is found to be unsuitable, studied are to be stopped and the site restored. DOE is then to seek new direction from Congress. Two years later Congress announced that a repository would open in 2010. The state of Nevada charges that the choice was political, but DOE to this day perseveres in its studies of the Nevada site.

The year 2010 was too distant to suit utilities that had tons of irradiated fuel on their hands. The Nuclear Waste Amendment Act of 1987 therefore authorized the Department of Energy to select one site for temporary storage of irradiated fuel, a Monitored Retrievable Storage site or MRS. The amendment stipulated that a construction authorization for a deep-underground final repository had to be issued before an MRS could accept waste. The proposed MRS has been a bone of contention between the Department and antinuclear activists to this day. Like the deep underground repository, no proposed interim storage sites has as yet become reality.

Low-level waste

In 1981 the NRC issued a draft of new siting regulations for radioactive landfills. The proposed regulations broke down low-level waste that is suitable for shallow land burial into three categories: A, B, and C, with C being the most radioactive; and they specified how each category was to be managed. Though far from perfect, the draft represented a serious attempt by the NRC to remedy past problems. Unfortunately the agency caved in to industry pressure, and greatly weakened the final regulations, which it released in 1982. For instance, the NRC raised the upper limits for the radionuclides iodine-129, nickel-59, nickel-63, niobium-95, strontium-90, and technetium-99 in C waste by a factor of 10. It raised the limit for carbon-14 in activated metals also by a factor of 10, and it eliminated the upper limit for carbon-60, which had been 70,000 Ci/m3. These changes meant that various highly radioactive waste that would, under the proposed regulations, have exceeded the limits for Category C could now go into landfills.

Costs that waste generators had to pay for waste disposal were escalating for waste producers because only three landfill sites (Barnwell, Richland, and Beatty) still accepted waste from utilities. To ease the burden on producers, the NRC redefined certain wastes as "below regulatory concern" (BRC). The Commission allowed waste with less than 0.05 microcuries per gram of tritium or carbon-14 to be disposed of in municipal landfills or down the drain. It also, on occasion, granted exemptions from disposal regulations to individual generators for specific wastes [Resnikoff 1987, pp. 45-51].

In 1988 Envirocare of Utah, Inc. opened a low-level waste site in Utah's West Desert, approximately 80 miles west of Salt Lake City. Initially the site was licensed to receive only Naturally Occurring Radioactive Materials (NORM). Accordingly Envirocare's first project was disposal of contaminated soils from EPA's Denver Radium Superfund Site. Envirocare has since expanded its operation to receive various types of Category A low-level waste, byproduct material, and mixed waste (waste that is radioactive and chemically toxic). However, reception of large volumes of contaminated soil has remained the primary focus.

In 1980 Congress passed the Federal Low-Level Radioactive Waste Policy Act that mandates that each state must take title to and "provide for" the disposal of all "low-level" waste generated within its boundaries. To encourage development of disposal sites but limit their number, it allows states that form waste disposal compacts to exclude from a regional compact facility the "low-level" radioactive wastes generated outside the compact region. Amendments in 1985 set a series of deadlines.

By January, 1988 compacts were to select a host state, and the selected host or individual non-member state had to have a schedule for siting a low-level landfill and applying for a license. States not in compliance by 1988 were to face denial of access to the three operating waste facilities. After January, 1996, states were automatically to take title and possession of waste, and liability for damages incurred [Resnikoff 1987, p. 53].

Under the Waste Policy Act, the sailing has never been smooth. In the 1980s citizens in various states organized statewide initiatives calling for the withdrawal of their respective states

from the compacts that they had joined. An attempt by the Central Interstate Low-Level Radioactive Waste Compact to site a dump in Nebraska is still in the courts in 2003.

Members of the Central Interstate Compact, formed in 1983, are Arkansas, Kansas, Louisiana, Nebraska, and Oklahoma. A coalition of out-of-Nebraska utilities paid for lawyers to oppose a 1988 citizen initiative. Keen interest in the referendum was shown by U.S. Ecology (formerly the Nuclear Engineering Company) and the multinational Bechtel Group, which had a contract to build a new $40 million waste facility in Nebraska. According to *In These Times*, the League of Women Voters had a $50,000 grant from the companies to help search out suitable sites in the state. The League had previously received a $30,000 grant in California (Aug. 31 to Sept. 6, 1998). Nebraska officials eventually refused to license the dump because they were worried that the site would pollute the water at the proposed site in Boyd County [Bauer 2002].

Citizens were learning that radioactive wastes include many long-lived isotopes that will be a problem well beyond the lifetime of state monitoring and waste facility programs. The dismantling of nuclear power plants, for example, would entail far more than possible exposure to the predominant radioactive cobalt-60 that has a half life of only 5.7 years. Marvin Resnikoff and co-workers pointed out that the activated metal in reactors is contaminated with nickel-59 and niobium-94. They represent only a small fraction of the radiation inventory of closed nuclear facilities but they have half lives respectively of 80,000 years and 20,300 years [Norman 1982, p. 377].

Decommissioning

The International Atomic Energy Agency (IAEA) defines three methods of reactor decommissioning: Immediate Dismantling or Early Site Release/Decon; Safe Enclosure or Safestor(e) (earlier known as mothballing); and Entombment. The terms describe the processes. In Decon, dismantling and decontamination begin within months or years of the reactor shutdown. In Safestore dismantling and decommissioning are postponed for several decades. Meanwhile, the reactor, which has been placed in a configuration for safe storage, is monitored. This approach has the advantage of allowing much of the radioactivity in radionuclides such as cesium-137 (half life of 30 years) and cobalt-60 (half life of 5.5 years) to decay before workers undertake dismantling and decontamination. In Entombment, the reactor is encased in concrete or other durable material. The structure must be maintained and monitored by the utility until the utility can show that radioactivity has decayed to a level that the NRC has determined is acceptable. The utility then loses its liability; ten years later the NRC ceases to regulate the site at all. Utilities may combine Decon with Safestore, that is they may use Safestore for one portion of a plant and Decon for another.

Whatever method is used, the irradiated fuel in the reactor is removed from the core after shutdown and stored in an on-site pool for at least five years before it may be shifted to more permanent storage. Furthermore, The NRC requires that decommissioning be accomplished within sixty years, although exceptions may be made to protect health and safety. Decommissioning is followed by license termination activities. When decommissioning and

license termination activities have been completed to the satisfaction of the NRC, the NRC terminates the plant's operating license.

Shippingport, the first commercial scale nuclear power plant, ceased operation in 1982. Congress asked the US Department of Energy (DOE) to decontaminate and decommission it. Using it as an example of Decon, the agency began dismantling the nuclear portion of the plant three years after shutdown. The agency shipped the resulting waste to its facilities in Hanford and Idaho. The reactor vessel, which weighed 153 metric tons, was sent intact to Hanford. After decontamination operations at the Shippingport site, the NRC released the site for unrestricted use in November 1987. The total cost of the Shippingport operation was $91.3 million or $1.267 million per MW. This is substantially less per MW than would be the cost of dismantling a large commercial reactor under the regulations of the 80s. The vessel on a 1000 MW reactor would be likely to weigh 1000 metric tons or more and would have to be cut up before shipment. Furthermore, federal low-level waste sites are not an option for the waste from commercial nuclear plants today [Wise-Amsterdam 2003; Federation of American Scientists 2003].

In the 1970s only three commercial reactors with a capacity of 100 MWe or more were shut down (Indian Point 1, Dresden 1, and Three Mile Island 2). In the 1980s, only two such plants, Rancho Seco and Shoreham, permanently ceased operation, and they did not do so until 1989. The owners of Indian Point, Dresden, and Rancho Seco opted for Safestore (Rancho Seco was eventually switched to Decon).

Decon was selected for Shoreham, but actual dismantling/decontamination did not begin until 1992. Furthermore, the plant was atypical because it had been shut down by New York's public-utilities commission after it had operated at 5% power for the equivalent of only three full days of service and was thus relatively lightly contaminated [NukeWorker 2003].

The Three Mile Island 2 accident led to various post-accident measures at that reactor. In 1980 some 43,000 curies of radioactive Krypton-85 and other radioactive gasses were vented directly into the atmosphere [Epstein 1998]. The reactor vessel head was removed in 1984. Between 1985 and 1990 the reactor was "defueled." Shipment of a portion of the reactor core debris to Idaho National Engineering Lab began in 1986. Accident-generated water was evaporated between 1991 and 1993 [NRC (Three Mile Island) 2003]. According to the Web site of NukeWorker, "The reactor coolant system has mostly been decontaminated, the radioactive liquids treated, most components shipped to a licensed low-level waste disposal site." However, as of 2003, dismantling of the reactor as a whole has not taken place. Nor has all the fissile material been removed from the core. According to Eric Epstein of TMI-Alert, Dr. Michio Kaku of City University of New York found in 1993 that estimates of core debris ranged from 608.8 kg to 1322 kg. [Epstein 1998]. No more about the quantity of core debris is known in 2003, Epstein tells us. General Public Utilities Nuclear Corporation, the owner, plans "to keep the facility in long-term, monitored storage until the operating license for the TMI-1 plant expires in 2014, at which time both plants will be decommissioned" [NRC (Three Mile Island) 2003].

Safety

The explosion at Chernobyl reactor number four in the Ukraine on April 26, 1986, overshadowed all other accidents in the 1980s. At TMI, a containment structure held most of the radioactive materials within it, but at Chernobyl a steam explosion tore the top off the reactor and destroyed the reactor building. The Soviets specified that there were 31 direct fatalities. The actual number will never be known. In 2001, Sergei Korsunsky, science attaché at the Ukrainian Embassy in Washington told a reporter that 600,000 emergency workers were needed to cover up the fire with sand and cement and that up to 80,000 of them died. Indirect effects from fallout and contamination are even more difficult to calculate. "In the civilian population," Korsunsky said, "we estimate about 3.5 million people were exposed to harmful doses of radiation. What is most terrible is that at least 1.5 million children were exposed." The biggest long-term problem is thyroid gland cancer from radioactive iodine isotopes [Witherspoon 2001]. One hundred and thirty-five thousand people were evacuated, after delays, from an exclusion zone 30 km in radius and from 113 villages outside this zone. The Soviets admitted that 80 million curies of radioactive isotopes were released into the atmosphere [Makihijahni and Saleska 1996, p. 123].

In many ways Chernobyl greatly exceeded TMI in the size of the impacted area and the damage. The disaster was first picked up on outside monitors in Sweden, hundreds of miles from the Ukraine. The problem transcended national boundaries as would accidents at most of the European power plants; plants are generally built where water for cooling is available and, in Europe, those sites are often on boundary rivers. The fact that outsiders had to give the alert is quite telling. In fact, an article in the *International Herald Tribune* by one of the authors of this report was the means by which residents of Moscow first learned of the accident. Once again the lack of access to vital information was demonstrated.

Europe reacted with greater alarm than the United States, mostly because of proximity to the plant and because of the actual fallout experienced. Some estimate that for months after the accident as many as one-fifth of Europe's population altered its diet. Vegetables were destroyed, milk consumption restricted, fresh water fishing discouraged. The Lapps of Sweden saw almost all of their reindeer meat staple declared unfit for human consumption. The French government attempted to downplay the accident, and did not issue timely warnings of fallout to residents. The cover-up eventually led to suits filed by French residents who became ill after staying outdoors in the fallout when they should have been under cover. The International Atomic Energy Agency sat paralyzed and ineffective throughout the critical period following the accident.

The political climate changed dramatically throughout Europe after Chernobyl with massive demonstrations in West Germany and Italy and concern shown by leaders on both the Left and Right. Public opinion in these countries reached high marks of opposition, with 83% of the United Kingdom citizenry opposing the building of new nuclear power plants. Some 3000 Poles signed a petition to halt construction at a particular plant. The Danish Parliament asked Sweden to shut down its Barseback nuclear plant, which is only 20 miles across the Strait from Copenhagen. German and Luxembourger opposition mounted in the form of demonstrations to

oppose the building of the nearby French Cattennom complex (four 1,300 MW reactors). Even in France, where nuclear power and patriotism are intertwined, over half the people polled after the accident were against new plants [Flavin 1987, pp. 63-66].

Chapter VII

The 1990s and Early 2000s: An Aging Industry

Mary Byrd Davis

The decade of the 1990s and the early years of the 2000s saw nuclear power electricity generation provide approximately one fifth of the electricity produced in the United States (19% in 1990,19.8% in 2000, 20.3% in 2002). As of 2003, several states received half or almost half of their electricity from nuclear power plants: Vermont 67%; South Carolina 55%, New Hampshire 53%; Illinois 50%; New Jersey 49%.

Between the beginning of 1990 and the end of 1998 eight reactors shut down prior to the expiration of their licenses, and three, Comanche Peak 1 and 2 and Watts Bar 1, under construction since the 1970s, began operation. As a result the total number of operable reactors declined to 104 by the end of 1998 and then remained stable. One of the 104 operable units is Browns Ferry 1, which has been shut because of an accident since 1985. No new nuclear reactors were ordered in the 1990s or early 2000s.

Despite the decline in the number of operable units between 1990 and 2003, the production of electricity increased. The operating reactors generated 576.9 billion kilowatt hours net in 1990; 753.9 in 2000; and 780.1 in 2002. Generating capacity also increased but only slightly because of the shutdown of the eight reactors: from 98,200 MWe in 1991 to 98,530 MWe in 2003 [World Nuclear Association 2003]. The reason for the growth in output despite a decrease in the number of plants is not reassuring. Reactors are being pushed to their limits.

In the 1990s and the early 2000s, questions about reactor safety, which first became a national issue with the accident of Three Mile Island, remain unresolved; radioactive waste is a growing problem; the industry has begun restructuring itself in ways scarcely compatible with its responsibilities to US citizens; and the nation as a whole has become for the first time conscious of the risk of nuclear terrorism. We shall discuss the first three subjects in this chapter but shall leave to the following chapter the significance of the September 11, 2001 attack and the administration's response to this attack as they relate to the nuclear industry.

Reactor safety

The aging that first became obvious in the 1980s continued as plants came closer to the end of their originally projected lifetimes of about four decades. Some plants were essentially rebuilt during the 1990s for it was far more feasible to improve an existing plant than it was to attempt to win approval and construct a reactor on a new site from scratch.

Meanwhile, various problems that had existed for years remained unsolved. The Union of Concerned Scientists in September 2003 called attention to a problem with the emergency cooling systems in pressurized water reactors. The emergency cooling system should cool the reactor if a primary coolant pipe that is kept under high pressure breaks. The emergency system first draws on water in a tank outside the reactor dome and then turns to water that has accumulated in the reactor basement during the accident. The water in the tank could be exhausted in as little as 14 minutes. If debris has entered the water in the basement, the debris could clog screens over the pipes that lead to the emergency pumps and allow a melt down. The NRC has long known about the problem and in 1996 classified it as serious. The agency now anticipates that the problem will be corrected by early 2007 [Wald Sep. 8, 2003].

In all fairness, the number of core meltdown problems predicted for the 1990s did not occur. (Extrapolating from the reactor time up to the Three Mile Island and the Chernobyl accidents, researchers had predicted three additional core-damaging accidents by the year 2000.) Furthermore, the widespread concern about "Y2K" (Year 2000) when computers might be unable to switch to the new millenium proved to be largely without foundation. The Nuclear Energy Institute reported on November 1, 1999 that "all but two reactors are Y2K ready"; and, in fact the turn of the century saw no nuclear accidents. Nevertheless, in 2002 a problem that could have led to a catastrophic accident if uncorrected was found at FirstEnergy's Davis-Besse plant east of Toledo. If the NRC does not force plant owners and operators to take safety seriously, this problem may prove to be just a foretaste of what is to come.

Davis Besse

In March, 2002, during a shutdown for maintenance and refueling, engineers at Davis-Besse discovered that boric acid had eaten a hole as big as a bread box in the six-and-a-half-inch thick, carbon steel cover of the reactor vessel. Only a three-eighth-inch barrier of stainless steel was preventing radioactivity from escaping. The boric acid, diluted in the reactor's cooling water, had leaked out of the vessel around several control rod nozzles that penetrate the cover. Between November 2000 and April 2001, cracks around similar nozzles had been found at nuclear reactors in Arkansas and South Carolina and, as a result, the NRC had requested that the nozzles at Davis-Besse be inspected by the end of 2001. On the basis, that Davis-Besse had shown no signs of a problem, FirstEnergy Corp., owner of Davis-Besse, had tried to delay the inspection until April 1, 2002, but had been given only permission to postpone the inspection until its planned 2002-shutdown at the plant, which began February 16.

FirstEnergy purchased a never-used lid as a replacement from a Michigan utility after the NRC criticized its plan to patch the old lid. Installation of the new cover necessitated cutting a 20 foot by 20 foot hole in the 300-foot-tall steel liner of the containment building. David Lochbaum of the Union of Concerned Scientists was concerned that bacteria in groundwater that had penetrated the base of the concrete containment building had corroded the steel liner. Only after prodding from the NRC, did FirstEnergy agree to conduct a pressure test of the liner before restarting the shutdown plant [Mangels and Funk 2002]. As of October 2003, the plant was still shutdown, and FirstEnergy was awaiting a decision on the restart by the NRC.

A report by a team of nuclear experts put together by FirstEnergy and submitted August 15, 2002, to the NRC states that "management and human performance isues" were behind the failure to maintain safety at Davis Besse. Noting specific safety programs with which FirstEnergy did not comply, they stated that FirstEnergy "failed to maintain the proper balance between electricity generation and nuclear safety goals" [PR 2003]. By August 2003, federal investigators and even FirstEnergy management agreed that the root of the problem was that employees were afraid to call attention to safety problems. They "either overlooked or downplayed" numerous warning signs, David Lochbaum, who interviewed the staff, states [Dao 2003]. In a pressurization test of the reactor in October 2003, the equipment functioned properly but the operators made mistakes that interrupted the test. The NRC was therefore not convinced that the "safety culture" at the plant had been sufficiently improved to allow restart [Funk and Mangels 2003].

It should be noted that as of October, 2001, FirstEnergy intended to seek a twenty-year extension of its license to operate Davis-Besse, which is due to expire in 2017. Also, FirstEnergy planned to improve the plant to increase its power output by fifteen percent over five years, i.e., from 935 MW to about 1060 MW [FirstEnergy Plans 2001]. FirstEnergy's desire to operate Davis-Besse to the maximum is an example of a trend.

License extension

License extension is becoming the rule. The Nuclear Regulatory Commission (NRC) licensed commercial reactors for 40 years of operation each. In the 1990s utilities began to request 20-year extensions of their licenses that would allow these reactors to operate for a total of 60 years each. The first power plant to receive an extension was Calvert Cliffs. The two units of Calvert Cliffs received their original licenses in 1974 and 1976 respectively. They would have expired in 2014 and 2016 respectively. In 1999, the licenses were extended to 2034 and 2036. By August 2003, 16 reactors had received 20-year extensions. Utilities had filed license renewals for 14 additional reactors. Over the next six years, the Nuclear Energy Institute expects companies to seek renewals for 20 more units [Nuclear Energy Institute 2003].

Increases in output

At the same time that the NRC is renewing licenses, it is increasing the licensed generating capacity of numerous reactors. Uprates began in the 1970s with approvals first going to at Calvert Cliffs (5.5% each), and then to Millstone 2 (5%) and H. B. Robinson (4.5%). The practice continued in the 1980s with a total of 9 uprates, but the pace quickened greatly in the 1990s with 33 uprates and then in the 2000s with 46 uprates as of March 2003. In 2002 the NRC uprated the capacity of nine of eleven units in Illinois [US DOE 2003]. The NRC decided in 2003 to allow Indian Point 3 near New York City to increase its output by 1.4% to 1041 MWe, not a large increase, but bizarre, because the very authorization of Indian Point 2 and 3 to operate is being fiercely challenged not only by antinuclear activists but by municipalities and government officials, who fear that the New York City area cannot be adequately evacuated in case of an emergency. As of March 2003, the NRC had seven requests for increases under review and expected a total of 35 additional requests within the next five years.

Typically the output of a reactor is increased by using more highly enriched uranium fuel, which augments the production of thermal energy and thus of steam. To accomplish the change safely, reactor components such as pipes and valves must be able to accommodate the increase. Therefore a large increase is likely to involve modifications to certain components, even in some cases the main turbines.

Most of the increases in generating capacity are small, like that of Indian Point 3. However, Entergy, which recently bought Vermont Yankee, is seeking a 20% (110 MWe) increase in the generating capacity of that plant to 620 MW. The increase is being hotly contested.

Moreover, the increases add up. As of April 2003, power uprates had resulted in an increase of 4022 MWe at existing plants, the equivalent of more than three new nuclear plants. According to an NRC fact sheet on Power Uprates, the NRC anticipates uprate requests in the next five years that would add another 2270 MWe to the nation's generating capacity, the equivalent of almost two additional new plants [Nuclear Regulatory Commission (Power Uprates) 2003].

Meanwhile, owners are raising the efficiency and therefore the output of their plants by

operating them with fewer and/or shorter shutdowns for refueling and maintenance. Average net capacity factor of US plants was 90.4% in 2002 according to the Energy Information Administration's Web site, i.e., plants on average were producing 90.4% of the net power that they would produce if all reactors were running at their generating capacity every day of the year. This factor was up from 66.0% in 1990 and 88.1% in 2000. (Figures from the Nuclear Energy Institute differ slightly from those of the Energy Information Administration as a result of differences in the methods of calculation.)

New roles for reactors

Furthermore, nuclear power plants are being assigned new roles: producing tritium and rendering plutonium unsuitable for use in nuclear weapons.

The civilian atom and the military atom have always been intertwined. Our chapter on the 40s and 50s indicates that the civilian nuclear program was an offshoot of the military program. Furthermore, the early steps of the fuel cycle: mining, milling, conversion, and enrichment are basically the same and may be carried out in the same facilities whether the goal is uranium for weapons or uranium for nuclear power plants. Nevertheless, the United States has prided itself on maintaining what it regards as a line between civilian nuclear and military nuclear programs. The United States has not produced materials for weapons in civilian nuclear power plants.

The United States is now abandoning its own distinction. In 2002 the NRC licensed TVA's Watt's Bar reactor and its two Sequoyah reactors to produce tritium for nuclear weapons. Tritium, used to boost the yield of thermonuclear weapons (hydrogen bombs), is an essential component in these weapons. It has a half life of only twelve years. Thus the tritium in nuclear weapons gradually decays and must be replaced if the weapons are to remain viable. The United States has not produced any tritium since 1988 when it closed a special production facility at DOE's Savanna River site. It has been replacing the decayed tritium in weapons in the nation's stockpile with tritium from dismantled weapons. However, the military claims that it will need a new supply of tritium by 2005 if it is to maintain the United States stockpile at the levels permitted by the START treaty.

Tritium can be made by irradiating lithium rods in a reactor. Tritium began production in the Watt's Bar reactor in October, 2003 and was expected to begin in Sequoyah 1 later in the fall and at Sequoyah 2 in 2004. At the end of each reactor's 18-month fuel cycle, the irradiated lithium rods will be shipped 350 miles to the Savanna River Site for extraction of the tritium in the Savanna River Tritium Extraction Facility (TEF) now under construction.

At the Savanna River Site, preparations for another project relating to weapons material are underway. US DOE intends to render 34 tons of plutonium removed from old nuclear weapons unsuitable for new weapons by incorporating the plutonium in a type of reactor fuel known as MOX (Mixed Oxides of Plutonium and Uranium) and irradiating the fuel in civilian reactors. Russia is also to incorporate 34 tons of weapons plutonium in MOX.

MOX has never been manufactured for or used in commercial reactors in the United States, although it is made for and used in them abroad. In March 1999 DOE awarded a contract to a consortium known as DCS for design, construction, operation, and eventual deactivation of a plant at Savanna River to make MOX. The consortium plans to irradiate the MOX fuel in Duke's Catawba (York, South Carolina) and McGuire (Huntersville, North Carolina) reactors. Duke Engineering Services is a member of DCS.

Construction of the fuel fabrication plant is dependent on licensing and financing. The NRC released its draft Environmental Impact Statement in February 2003. It recommended preliminary approval of plans to build the plant. Meanwhile, Duke has requested approval from the NRC for use of a small quantity of MOX in one of its plants beginning in 2005. Larger scale use would begin around 2008 [Nowell 2003].

The plans are being fought by numerous safe energy, environmental, and peace organizations, which advocate rendering the old weapons plutonium unusable by mixing it with nuclear waste and solidifying the mixture. They point out, among other things, that use of plutonium in nuclear power plants sets a bad precedent, as it could lead to the widespread adoption of MOX fuel in this country. Use of MOX in civilian reactors and the transportation of MOX increases the risk that terrorists or rogue nations will get hold of plutonium. Furthermore, the use of MOX fuel in a reactor increases the likelihood and the severity of an accident.

Safer reactors?

The nuclear industry tacitly admits that existing reactors have safety problems, as both the federal government and private firms are investing in the development of what they believe to be safer reactor technology.

Some scientists hope that fusion will eventually usher in a safer and more economic era of nuclear power. While fission reactions release energy as particles fly apart - and into the environment - fusion reactions snare energy released as particles bind together. This technology, which is still in the initial stages of development, involves using magnetic fields to confine tritium or a mixture of deuterium and tritium raised to a high temperature in the form of plasma. The equipment in which the tritium and deuterium are confined is known as a tokamak.

In February 2003, the United States joined international negotiations to site a giant tokamak, Iter (International Thermonuclear Experimental Reactor), to carry out experiments in fusion. The United States also has a domestic fusion program [Iter 2003]. Nevertheless, major technical problems must be resolved before magnetic confinement fusion can generate energy even at a laboratory scale. Furthermore, the technology poses health problems, in particular because it involves large quantities of tritium.

If new reactors are built in the United States in the next decade, they will be based on fission, not fusion, and presumably will incorporate designs that the US Nuclear Regulatory Commission (NRC) has already certified or will soon certify. The Energy Policy Act of 1992

provided for certification by the NRC. Use of a design that has been certified means that the public will not be able to bring up safety issues related to the design during the licensing of a plant.

Three designs have already been certified: System 80+ and AP600, PWR designs belonging to Westinghouse BNFL, and the ABWR (Advanced Boiling Water Reactor) associated with General Electric, Toshiba, and Hitachi. Of the three, only the ABWR has actually been deployed (two reactors operate in Japan) and only the ABWR design is currently being promoted for construction in the United States. All three certified designs offer safety concepts regarded by the industry as more advanced than reactors now operating in this country.

Undergoing certification is Westinghouse BNFL's AP1000, an enlargement of the AP600. The most recent version has a capacity of 1117 MW. The AP1000 is "a much simplified design that is intended to cut the material and construction costs of the plant" and incorporates "innovative passive safety features" [US DOE 2003]. However, is it safe enough?

Paul Gunter of the Nuclear Information and Resource Service notes that the AP600 and AP1000 reactors have containment structures only 2.5 feet thick in order to reduce construction costs. Furthermore, as a passive safety feature, the water storage tank for the emergency core cooling system is constructed on top of the reactor and will send water to the reactor by means of gravity rather than pumps and motors. This means that the tank is outside the primary containment structure [NIRS June 26, 2002]. Westinghouse submitted its application for certification of the AP1000 in June 2002 [NRC 2002].

Six designs are undergoing pre-certification. They include Atomic Energy of Canada Limited's ACR700, an advanced CANDU reactor. CANDU reactors, which use natural rather than enriched uranium, are in operation in Canada and other countries. Also undergoing pre-certification is General Electric's ESBWR, a BWR merging and improving on earlier GE designs. It includes new passive safety features and is intended to reduce construction and operating costs.

The reactor undergoing pre-certification that may be attracting the most attention, however, is the PBMR (Pebble-bed Modular Reactor). The PBMR is a Very High Temperature Gas Reactor - a gas, helium cools the fuel and transfers heat to the generator. A small PBMR began operating at a German research center in the 1960s. The South African utility Eskom, in cooperation with BNFL, is now proposing the PBMR for commercial use in South Africa. Each PBMR would have a capacity of 165 MW, the smallest of any of the advanced reactors undergoing NRC pre-certification. The fuel would be uranium enriched to about 8%, a higher enrichment than that used in BWRs and PWRs. The uranium is in the form of grains, coated with carbon, and placed inside spheres approximately the size of billiard balls. Mixed in with the spheres are balls of graphite without fuel that serve to absorb neutrons and moderate the reaction.

The PBMR has certain advantages. The helium is an efficient carrier of heat, does not pick up radioactivity, and is not corrosive. Furthermore, helium can be fed directly into a turbine. The PMBR can be refueled without being shut down. In addition, according to

proponents, the uranium in the fuel pellets will not melt and emit radiation into the environment, even if all the helium coolant leaks out of the reactor.

However, critics are unconvinced. They are concerned that the pebbles filled with fuel could leak and that the graphite pebbles would catch fire if a breach in the reactor allowed oxygen to come into contact with them. Moreover, the PMBR creates larger volumes of radioactive waste than the PWR and the BWR [Haynes 2003; Pebble 2002].

Waste

However good or bad the industry's ideas for new types of reactors, they do not end the danger presented by the reactors already in operation and they do not solve the radioactive waste problem, which in the 1990s and early 2000s loomed large. Below is a type by type survey followed by the presentation of two specific waste streams.

Mill Tailings

Under the Uranium Mill Tailings Remedial Action Project, the Department of Energy, in cooperation with states, Indian tribes, and owners of specific sites, has carried out remediation activities on more than twenty sites where uranium was milled from the early 1940s through 1970. The aim has been to store the tailings, still normally near the point of production, in such a way as to prevent further contamination of the environment, and to clean up existing contamination. The total cost of the program, as of December 31, 1999, was $1.48 billion [Energy Information Administration 2001]. Tailings piles are yet to be remediated at additional sites. The 10.5 million tons of tailings dumped by the Atlas Corporation mill on the Colorado River near Moab, Utah are a notorious example [NuclearFuel 2000]. They amount to more than six times the volume of the rubble taken from the collapsed World Trade Center. As of June 2003, DOE was studying four options for managing the waste, including capping the tailings in place and burying the tailings 17 miles away at Klondike Flats [Fahy 2003]. (The only mines operating in the United States at the end of 2002 were "in situ" leaching operations. These operations do not produce tailings, since uranium is leached underground from the ore in which it is found; but these operations are likely to contaminate groundwater.)

High-Level Waste

Irradiated fuel from nuclear power plants is still stored on a "temporary basis" at reactor sites. In 2001 DOE formally recommended for a permanent repository the Yucca Mountain, Nevada site, which the agency had been studying since the 1980s. President Bush approved the site February 15, 2002, and Nevada's governor, Kenny Guinn, announced the state's official disapproval April 8. The US House of Representatives on May 8 and the US Senate on July 9 overrode Nevada's objection.

However, the opening of the site is not a foregone conclusion. The state of Nevada is suing President Bush and other parties to the decision to construct a repository at Yucca

Mountain. Furthermore, the NRC will have to determine whether to license the site, and the Commission has presented DOE with a list of 239 "unresolved" scientific issues on which the NRC requires further information. The NRC will be under intense pressure to issue a license, but many of the questions will not be easy for DOE to answer. The subjects range from seismic risks, through "thermohydrologic flow" to resistance of containers to corrosion. The DOE hopes to turn over all the answers by the end of 2004, but the General Accounting Office believes that DOE will not be able to complete them before 2006. The earliest date at which a repository at Yucca Mountain can open is 2010 [Grove 2002].

The Yucca Mountain repository, as now designed, would store only 70,000 tons of irradiated fuel. About 44,000 tons of fuel are already stored in pools and casks at reactor sites. The quantity increases by about 2000 tons a year. Furthermore, 2500 tons from research reactors, naval reactors, and reactors to produce material for weapons may need disposal. The available space in the repository could thus be exhausted shortly after it opens.

Impatient for a place to store their irradiated fuel, eight utility companies, in the consortium Private Fuel Storage, LLC (PFS), asked the NRC for a 20-year license for an above-ground irradiated fuel storage facility on the reservation of the Skull Valley Band of the Goshute in Utah. PFS intended to store up to 44,000 tons of irradiated fuel on the reservation until a permanent repository opens. The Atomic Safety and Licensing Board ruled against licensing the storage site due to the credible risk posed by fighter jets that train in the Skull Valley area near the proposed facility. PFS in response proposed to reduce drastically the quantity of fuel stored [Kemp 2003]. In another approach to irradiated fuel, the Bush administration is advocating recycling. The version of the energy bill passed by the Senate in 2003 would create an Office of Spent Nuclear Fuel Research, which would "require research on both reactor- and accelerator-based transmutation systems" and "on advanced processing and separations." The House version would require an advanced fuel "recycling" technology research and development program to evaluate proliferation-resistant fuel recycling and transmutation. In reference to irradiated fuel, recycling involves what is called reprocessing, treating irradiated fuel to separate the constituents. Plutonium is one of the constituents that is separated out. Thus reprocessing increases the risk of nuclear proliferation. Had the irradiated fuel now awaiting a repository been reprocessed, the United States would have already produced some 400 tons of separated plutonium.

France, which has long practiced reprocessing of civilian fuel as a so-called means of waste management is edging away from the process. The French Atomic Energy Commission has begun research on centralized above-ground or near-surface facilities for long-term storage of irradiated fuel. The United Kingdom will end reprocessing when British Nuclear Fuels Limited (BNFL) shuts down its two plants in 2010 and 2012 respectively.

The French and the British use the "wet" Purex process. The Bush administration's energy policy proposes that the United States develop and deploy a dry process known as "pyroprocessing." Proponents of the process say that it is proliferation proof, because the plutonium that is retrieved is contaminated with some uranium, other transuranic elements, and

some fission products; but the contamination is not such as to prevent terrorists from using the plutonium in a nuclear device; and the process can be altered to separate out pure plutonium [Lyman 2001; Makhijani 2001].

In considering how to manage irradiated fuel, transportation is a major issue. Trains and trucks loaded with fuel, whether on their way to temporary storage, a repository, or a reprocessing plant, are a dangerous proposition, from the point of view both of terrorism and of accidents [Resnikoff 1983]. DOE's Final Environmental Impact Statement on the Yucca site (Feb. 2002) included preliminary route maps. However, DOE has made no decision about what routes the fuel will take. As of mid-2002 it envisaged sending 90% of the waste by rail and 10% by road [Pianin and Dewar 2002].

DOE and the railroads have not agreed as to whether casks sent by rail will travel in trains dedicated to radioactive waste or in trains with mixed freight [Lortie 2002]. DOE spokesperson, Joe Davis, has been quoted as saying that actual transport routes "will be classified" and will be worked out with state and local officials [Associated Press 2002]. DOE, however, has been delaying making decisions about transportation while it has been concentrating on preparing a license application for the repository site. Transporting to Yucca Mountain 70,000 tons of irradiated fuel would require 2525 truck shipments each year for 38 years or 522 rail shipments each year for 38 years, supplemented 97 truck shipments a year from reactors without rail lines [Hartman and Bremner 2002].

The NRC requires that casks that carry irradiated fuel be able to resist "an engulfing fire" that burns at 1475 degrees Fahrenheit for half an hour. Transportation fires may burn hotter than 1475 degrees Fahrenheit and for a long time. The fire that began July 18, 2001, in a train carrying hazardous materials through a tunnel under downtown Baltimore and that lasted more than twenty-four hours has become a bone of contention in the debate as to whether transportation of irradiated fuel is safe. Marvin Resnikoff of Radioactive Waste Management Associates, working for the State of Nevada, found that had the train been carrying irradiated fuel "a significant release of cesium 134 and cesium 137" would have occurred. The cost of decontaminating a sixty-two square kilometer area (32 square mile area) after such a fire would be an estimated $13.7 billion [Lortie 2002]. A team working for the Nuclear Regulatory Commission (NRC), on the other hand, judged that a cask carrying irradiated fuel would have remained intact in the fire and that no radiation would have escaped. Robert Halstead, senior transportation advisor to the State of Nevada, has charged that researchers at the National Institute of Standards and Technology who participated in the NRC's study, felt that the NRC "leaned on" them to produce results supporting NRC standards. In any case, the difference between the results in the two studies seems to hinge in differences on assumptions and calculations as to whether and for how long the temperature in the tunnel was 1500 degrees or higher [Tetreault May 2003].

The NRC has not subjected to full-scale physical tests the casks currently licensed for transportation of irradiated fuel. (Casks that are now obsolete were the subject of limited physical testing in the 1970s.) The agency plans to change its approach, but critics charge that

the change is too little too late. An NRC Package Performance Study will submit just two cask designs to full-scale physical tests. The proposed study will not address questions of vulnerabilities to puncture, crushing force, submersion, or explosion. Furthermore, the tests are not scheduled to be completed until 2005, after the NRC will presumably have decided whether to permit the Private Fuel Storage site to open. The opening of the site would initiate a flood of cross-country shipments [Claybrook 2003]. Meanwhile the National Academy of Sciences is putting together a team of experts to look into the risks of shipping radioactive waste to Yucca Mountain. Casting some doubt on the objectivity of the study is the fact that it will be paid for not only by the US Department of Energy, the Nuclear Regulatory Commission, and the National Cooperative Highway Research Program, but also by the utility industry's Electric Power Research Institute. This study, like the NRC's cask study, will not be completed until 2005 [Tetreault February 2003].

Transuranic waste

DOE's Waste Isolation Pilot Project, a waste disposal site deep underground in a salt formation near Carlsbad, New Mexico, began receiving "transuranic waste" in 1999. This waste is largely, if not entirely, material resulting from the development and production of nuclear weapons.

Low-level waste

Most states have now entered into multi-state compacts. However, not all the compacts have as yet provided for waste disposal sites. As of August 2003, low-level waste was shipped to three waste disposal facilities: Chem-Nuclear's site at Barnwell, South Carolina; US Ecology's site at Richland, Washington (US Ecology is a subsidiary of American Ecology Corporation), and Envirocare of Utah's site in Utah. Only one of the three sites, Barnwell, accepts all types of low-level waste generated across the nation. Richland accepts low-level waste only from the Rocky Mountain and Northwest Compact states. Envirocare, because of the terms of its license, takes mainly large-volume, low-activity waste such as soil and mill tailings. Such waste is classified as Class A. The waste classified as "Classes B and C" are more radioactive and tend to contain isotopes with very long hazardous lives. Barnwell, which accepts "B and C" waste will stop receiving waste "from all but a handful of states" in 2008. In 2000 South Carolina entered into an Atlantic Low-Level Radioactive Waste Management Compact with Connecticut and New Jersey. The South Carolina legislature closed Barnwell to waste from states other than compact members as of 2008.

The State of Texas may step into the breech. In the spring of 2003 the Texas legislature passed a bill that allows a private company to operate a multipurpose national radioactive waste disposal facility in the state. The beneficiary of the legislation is expected to be Waste Control Specialists LLC (WCS), a Pasadena-based company. WCS already operates a 1338-acre waste treatment, storage, and disposal site for hazardous waste, toxic waste, and certain types of low-level radioactive waste, including "greater than Class C waste," within a 16,000-acre tract that it owns in Andrews County, West Texas. This site has a renewable seven-year license. The

legislation would make possible three separate waste sites. The first site could receive up to 162 million cubic feet of low-level radioactive waste (including up to 16 million cubic feet of B and C waste) from federal nuclear weapons production sites around the country; the second could receive "nuclear power plant and other 'compact' waste from around the country. (Texas and Vermont are in a compact agreement that allows governor-appointed compact commissioners to accept unlimited amounts of waste from other states to be disposed of in Texas)"; the third site will "accept a stew of hazardous and low-level radioactive waste." The legislation requires the State to take title to the compact waste when it arrives at the site. WCS would receive a 15-year operating permit but need not operate the site for all 15 years. Texas's two reactors are not scheduled to be decommissioned until 2030-2037. Therefore, Texas may have no place to put its own decommissioning waste when it needs one [Texas 2003].

The facility has yet to be licensed by state agencies. The Texas Environmental Quality Commission will begin receiving applications in early 2004 and is scheduled to select an applicant by 2005. Opponents call attention to the fact that the facility would be over the Ogallala aquifer [WISE/NIRS 2003].

"Slightly" radioactive waste

Since 1980, the NRC has tried to solve part of the low-level waste problem by deregulating the less contaminated (but vast) portion of this waste variously called by the authorities "de minimis" (i.e., "trivial" waste), "Below Regulatory Concern," and "Incidental Radioactive Material." The agency wanted to allow this waste to be dumped into municipal solid waste landfills and sewers or to be recycled into unlabeled consumer products. Congress in the Energy Policy Act of 1992 thwarted the agency's initial deregulation plans, but deregulation of slightly contaminated waste has since been revised under various guises [Johnsrud 2003].

In an attempt to legitimize its efforts, the NRC commissioned the National Academy of Sciences to provide recommendations on streamlining the release of these radioactive materials from regulatory control. However, in a report released March 21, 2002, the Academy's National Research Council declined to endorse or encourage the NRC to release radioactive materials from control, criticized the agency's efforts over the past sixteen years to do so, and asked it to work with the public and heed the public's concerns [NIRS March 2002].

On November 6, 2002, the NRC announced that it will proceed to a new rule making on what it is euphemistically entitling "Control of Solid Materials." The rulemaking, in which the public is invited to participate, is expected to take three years. Although the NRC is offering five alternatives and claims to be looking objectively at the issue, "the NRC Commissioners directed the staff to '…reiterate the Commission's continuing support for the release of solid material…'" [SRM 2002]. The four performance goals on which the agency bases its rulemaking include "maintaining safety, protection of the environment and common defense and security" and "reducing unnecessary regulatory burden on stakeholders," i.e., the nuclear waste generators. The two are incompatible, as reducing the burden for industry increases the risk to the public.

The five alternatives the NRC claims to be considering are 1) continuing releasing "slightly" radioactive waste into commerce on a cases by case basis and through license amendments as the NRC has been doing for years; 2) continuing releasing these materials within an acceptable dose range, which NRC will set up (doses to the public cannot be verified or enforced); 3) release for conditional or restricted use as in a bridge or pipeline (reuse of the materials after the restricted use will not be monitored); 4) disposal in an Environmental Protection Agency regulated landfill (wastes could go into municipal, industrial, or hazardous waste facilities not designed to isolate radioactive waste); 5) disposal in an NRC or Agreement state-licensed radioactive waste disposal site (this is the only alternative that prevents the dispersal of radioactive waste into commerce and unregulated facilities) [NIRS 2003].

Depleted uranium

Among the wastes that would be impacted by any new regulations allowing release of radioactive materials are around 700,000 metric tons of depleted uranium hexafluoride (UF6) stored in cylinders at the gaseous diffusion plants. The depleted uranium hexafluoride is a byproduct of the enrichment of uranium. Uranium hexafluoride is hazardous, whether or not it is depleted. If it escapes into the atmosphere, it reacts with moisture in the air to form hydrogen fluoride, a corrosive gas, and uranyl fluoride, a soluble compound, toxic from both a chemical and a radiological point of view. In 1998 Congress enacted PL 105-204, mandating construction of two facilities to convert the UF6 into a more stable solid. As a result of repeated delays in implementation of the law, Congress included in the anti-terrorism bill that the President signed in August, 2002, a requirement that DOE award a contract for construction of the two facilities within thirty days of the President's signature.

DOE awarded a contract for design, construction, and operation of two plants to Uranium Disposition Services. As of August 2003, DOE is preparing a draft Environmental Impact Statements for each of the plants. According to the 2002 legislation, construction is to start by July 31, 2004. The plants will be built at DOE's Portsmouth, Ohio, and Paducah, Kentucky sites. DOE will ship the depleted UF6 stored at its Oak Ridge site to Paducah for conversion. Whether the depleted uranium, after conversion, is to be buried as waste, made into containers for use within the nuclear industry, incorporated into items to be used outside the industry, or incorporated into weapons is still an open question. The use of depleted uranium in conventional weapons in the Gulf War, in Kosovo, and in Iraq is a subject of growing controversy, as the evidence that it has harmed the health of military and civilians is accumulating. [For example, Durakovic 2003].

Decommissioning

Another area that will be heavily impacted by the rulemaking is reactor decommissioning. The destination of slightly contaminated radioactive waste will affect the practicality and the cost of decommissioning. According to the report of the National Academy of Sciences released in 2002, the total estimated cost of disposing of all slightly radioactive solid

material - metal and concrete - at US power reactors under the no-release option is between $4.5 and $11 billion. The report notes that "clearance of all this material could allow the option of recycle or reuse … and would avoid essentially all disposal costs" [Committee 2003]. The utilities would, of course, have disposal costs for more heavily contaminated wastes, but these wastes would be small in volume compared to the waste released.

According to the Japanese government, a typical nuclear power plant that generates 1100 MW of electricity produces between 500,000 and 550,000 tons of waste when it is dismantled. (This is four times as much waste as would be generated by dismantling a normal office building with 4 basement levels and 22 above-ground stories.) Ninety-seven percent of the waste from dismantling a power plant can be disposed of as normal industrial waste rather than as radioactive waste if the industry is allowed to release "slightly" contaminated waste, the Japanese government estimates [Asahi Shimbun 2002].

In the United States utilities must regularly set aside funds for decommissioning their nuclear plants. As of 2000, the owner of a pressurized water reactor had to accrue a minimum of $289 million (1998 dollars) and the owner of a boiling water reactor a minimum of $359 million. Observers of the nuclear industry have until recently believed these funds to be insufficient. The price of decommissioning the small 179-megawattYankee Rowe reactor, which was shut down in 1991, went from $120 million to $450 million. Trojan and Maine Yankee also experienced growing decommissioning costs. In a report released in 1999, the General Accounting Office analyzed decommissioning funds accumulated by 76 licensees owning all or part of 188 operating or retired reactors. They found that under one assumption 36 licensees had failed to accumulate sufficient funds and that under another assumption 72 had failed to do so; however, ironically, corporations buying operating nuclear power plants today appear to view the plants as a bargain, in part because they believe that they will not have to spend all of the accumulated decommissioning funds on decommissioning. They are confident that release of slightly contaminated material will be allowed and that therefore dismantling costs will shrink greatly rather than increase [NIRS 2000].

As of 2003, fourteen units generating 100 MW or more of electricity had been permanently shut down. Two of these, Shoreham and Fort St. Vrain, had completed the decommissioning process and had had their operating licenses terminated. Seven of them are undergoing dismantling; five are in SAFESTOR. The fourteen reactors had stopped operating for financial reasons or safety reasons or, most frequently, a combination of both.

In December 1996 the Connecticut Yankee Atomic Power Company (CYAPCO), for example, decided to shut down Connecticut Yankee nuclear power plant in Haddam Neck on the Connecticut River. One account indicated that the decision was due to high operating costs and rising competition from other energy sources ($32.25 per megawatt hour as compared to $21.23 for other nuclear power plants and $19.78 for coal-burning plants). However federal nuclear inspectors had identified a host of safety problems both there and at the three other nuclear power plants in the state. Several months earlier the Connecticut Yankee plant had been shut down when the cooling water in the plant dropped dramatically, nearly causing the fuel to

overheat [Revkin 1996].

Connecticut Yankee is using the DECON approach, which it hired Bechtel Corp. to implement. In June 2003 Bechtel filed suit against the owner on the grounds that the company had failed to disclose years of "poor operation" at the site, including groundwater contamination, until Bechtel had agreed to a cleanup price and schedule. Also in June, Connecticut Yankee terminated its contract with Bechtel. Thus, as of August 2003, the dismantling was stalled.

The decommissioning of Maine Yankee is proceeding more rapidly, although the decision in 1997 to shut the plant down permanently was based on safety considerations. In 1995 a whistleblower within the plant reported serious safety problems to Bob Pollard of the Union of Concerned Scientists. The allegations were brought to the attention of the NRC which first reduced power by 10% and then in the summer of 1996 cited Maine Yankee for 16 violations of safety regulations. The NRC shut the plant down for resolution of safety problems in December of that year [Leon 1997]. In May 2003 the reactor vessel left by barge for disposal at the Barnwell site in South Carolina; and in the summer of 2003, Stone and Webster Engineering Corporation will demolish the containment structure.

The License Termination Plan had proposed that portions of the above-grade concrete from demolished buildings be "rubbilized" and left onsite in building foundations. After protests from the State of Maine and the Friends of the Coast Opposing Nuclear Pollution, the company decided to revise its plan and ship the radiologically contaminated above-grade concrete by rail to the Envirocare disposal site in Utah [Nuclear Regulatory Commission (Decom.) Aug. 2003].

On January 16, 1998, Commonwealth Edison, the nation's largest private nuclear utility operator, announced that it would close two of its twelve nuclear reactors because they were too expensive now that the industry was being deregulated. These plants, which sit side-by-side on Lake Michigan in Zion, Illinois (40 miles north of Chicago) were said to be shutdown for purely economic reasons, but opponents noted labor and safety issues were contributory to the final decision [Nation's 1998]. It was expected that the company would consider other closings in the near future. At the time, it was believed that the stage was being set for the major decommissioning of American reactors. However, the extension of the licenses of existing reactors is now the mode instead.

Industry restructuring

Consolidation

A wave of consolidation of ownership of US nuclear power plants has cast doubt on whether plant owners will pay for decommissioning or, in the event of an accident, meet even the slight requirements of the Price Anderson Act. At the close of 1991, the operable nuclear power plants were owned in whole or in part by 101 utilities [World Nuclear Association 2003]. Consolidation began in July 1999 with Entergy's purchase of the Pilgrim reactor in Massachusetts from Boston Edison. By mid-2002, 12 utilities owned 68% of nuclear operating

capacity. Subsequently Entergy purchased Vermont Yankee from Vermont Yankee Nuclear Power Corp. and FPL Energy purchased a controlling interest in the Seabrook plant in New Hampshire. In September 2003, British Energy announced that it will sell its share of AmerGen, which owns three reactors: Three Mile Island 1, Clinton, and Oyster Creek, to FPL Energy, a subsidiary of the US firm FPL group. It is unlikely that this sale will mark the end of consolidation. The World Nuclear Association has predicted that there may eventually be "only ten to twelve US nuclear utility operators" [World Nuclear Association 2003].

A report prepared for STAR Foundation and Riverkeeper, Inc. by Synapse Energy Economics examines the impact of consolidation on the financial stability of the industry. The large corporations that now own nuclear plants "have adopted business structures that create separate limited liability subsidiaries for each nuclear plant, and in a number of instances, separate operating and ownership entities that provide additional liability buffers between the nuclear plant and its ultimate owners." The limited liability structures enable plant parents/owners to avoid tax payments. "They also provide a financial shield for the parent/owners if an accident, equipment failure, safety upgrade, or unusual maintenance need at one particular plant creates a large, unanticipated cost. The parent/owner can walk away, by declaring bankruptcy for that separate entity, without jeopardizing its other nuclear and non-nuclear investments." The NRC doubts that it would be able to hold a parent corporation responsible for the liabilities incurred by a subsidiary. Specific areas in which consolidation may allow nuclear plant parents/owners to escape costs for which they would otherwise be held responsible include decommissioning costs and compensation payments under the Price-Anderson Act [Schlissel 2002].

Internationalization

A struggle through much of the 1990s in the American South involved a request by the international consortium Louisiana Energy Services (LES) for a license to open and operate a uranium enrichment plant. The eight-year controversy pitted the multiracial activist group "Citizens against Nuclear Trash" (CANT) against the LES company. The Nuclear Regulatory Agency's own licensing board had to make the final decision. The board first said that LES was not financially qualified, as it was a "shell" corporation designed to protect the parent companies in case of any unforeseen disasters. It later said that LES greatly underestimated the decommissioning costs. Finally it bestowed on LES the dubious distinction of being the only company ever to be denied NRC approval because of its environmental racism [NIRS 1997]. The NRC said that LES had not ensured that the proposed plant would not be a heavy burden on a 98% poor African-American population in the Center Springs and Forest Grove communities where the plant was to be located. Undoubtedly, the decision on May 2, 1997, was precedent-setting and will impact nuclear plant sitings well into the future.

The key player in the LES consortium was the Netherlands-British-German firm Urenco, which owned the centrifuge technology that was to be used at the plant. Although LES was defeated in 1997, it represents a trend that has become pronounced. Nuclear power is becoming less and less a means to energy independence for the United States. US companies do not mine

and mill the majority of the uranium used in US reactors, and our known uranium reserves are low. Furthermore, to carry out all but one of the basic steps in the US fuel chain, foreign companies are establishing themselves on US soil. Even LES is trying to make a comeback. Below we look at the fuel chain, step by step, in terms of the foreign factor.

Mining and milling

The mining of uranium ore in the United States is dwindling. Furthermore, foreign companies own the only two mines that were active as of the end of 2002, both in situ leach operations. (In in situ leaching, the uranium ore remains in the ground. A leaching liquid is injected into the ground through wells; the liquid, now bearing uranium, is pumped out through other wells.) No conventional uranium mills were processing uranium ore at the end of 2002. (Two, Canon City and White Mesa had alternate/byproduct feed operations.)

The United States produced a total of only 2.3 million pounds of U3O8 (uranium oxide) in 2002. In 2002 power companies loaded into US reactors fuel containing the equivalent of 57.3 million pounds of U3O8. Thus mines located in the United States produced the equivalent of less than one twentieth of the year's demand.

The two in situ leaching operations are Crow Butte in Nebraska; and Smith Ranch in Wyoming. Crow Butte and Smith Ranch are owned by companies that are 100% subsidiaries of Cameco. (Cameco acquired Smith Ranch in 2002 from a firm owned by the British company Billiton Plc.).

Known uranium reserves in the United States that are recoverable at a cost of $30 per pound of U3O8 total 266 million pounds; those recoverable at $50 per pound, total 89 million pounds. Thus US reserves are roughly the equivalent of five years or eighteen years supply respectively for US reactors. Total expenditures for uranium exploration and development in the United States in 2002 were $0.4 million, contrasting with $4.8 million in 2001 and $30.4 million in 1997 [Uranium Annual 2003].

Conversion

The United States has only one operating plant to convert U3O8 (uranium oxide), known as yellowcake, to UF6 (uranium hexafluoride), the feed for plants that enrich uranium by the gaseous diffusion or centrifugation method. The plant, Honeywell Specialty Chemicals in Metropolis, Illinois, has a nominal capacity of 12,700 metric tons of uranium per year [Steyn 2001; Uranium Institute 1998, p. 129]. It is owned by Honeywell International Corporation, based in Minneapolis. ConverDyn, a joint venture of Honeywell and General Atomics, markets the UF6 produced at the plant. A conversion plant owned by Sequoyah Nuclear Fuels in Gore, Oklahoma, stopped converting U3O8 to UF6 in 1992 and is now undergoing decommissioning.

The Metropolis plant does not have sufficient capacity to meet the conversion needs of US reactors, which total approximately 17,500 metric tons of natural uranium a year [World Nuclear Association 2000, p. 27].

Enrichment

Only one US company enriches uranium, the United States Enrichment Corporation (USEC). It is struggling to remain profitable, but at the present time does not have the capacity to meet the enrichment needs of US utilities.

USEC came into existence in July 1993 as a government-owned corporation to take over enrichment operations, which had formerly been run by DOE and its predecessors. In July 1998, USEC, through an initial public stock offering, became a privately owned company. USEC leases from DOE two enrichment plants, the Paducah Gaseous Diffusion Plant in Kentucky and the Portsmouth Gaseous Diffusion Plant in Ohio. For financial reasons, the company shut down the enrichment operation at the Portsmouth plant in May, 2001 and, with the help of government funding, put the plant on cold standby.

Since stopping enrichment at Portsmouth, USEC has been limited in its production capability. However, USEC's 10KT report to the SEC filed March 4, 2003 states "USEC estimates that the maximum capacity of the existing equipment [at the Paducah plant] is about 8 million SWU per year." (A SWU [Separative Work Unit] is a means of measuring the work of enrichment). The report continues, "USEC produces about 5 million SWU per year."

Even at 8 million SWU, Paducah would not be able to turn out enough SWU to meet the demands of US utilities if they were to try to buy enrichment services only from USEC. In 2002 US utilities purchased 11.5 million SWU (9.8 million of the SWUs were enriched outside the United States; 1.7 million within the United States) 5.2 million from USEC and 6.6 million from foreign sources) [US DOE 2003]. Furthermore, USEC cannot meet, with Paducah's production, the demands of its present foreign and domestic customers - approximately 11 million SWU per year.

To meet the needs of its customers and also to stay afloat financially, USEC depends on importing from Russia low-enriched uranium that has been downblended from highly enriched uranium removed from weapons. In USEC's 2002 fiscal year, the SWU component of the low-enriched uranium imported from the Russian Federation amounted to approximately 50% of USEC's supply mix (ie 50% of the total of the purchased and produced SWUs). According to USEC's 2002 Annual Report, the company expected the Russian SWU to again represent 50% in FY 2003. USEC pays less for a given quantity of the Russian uranium than it would spend to enrich an equivalent quantity of natural uranium at Paducah. It has the exclusive US right to this Russian uranium, because it is the only US executive agent for what is known as the US-Russian HEU accord, according to which the United States agreed to purchase over a twenty-year period, 500 metric tons of downblended weapons uranium from Russia.

A major reasons for USEC's financial difficulties is that the enrichment plants that USEC leases are more than forty years old and use a technology that is no longer competitive, largely because it requires large amounts of electricity. A gaseous diffusion plant typically demands 2,500 kilowatt hours per SWU. A centrifuge plant requires only 50 to 400 kilowatt hours per SWU. Two of USEC's competitors, Minatom in Russia and Urenco in Germany, the Netherlands, and United Kingdom, use centrifuges.

In 2002 USEC entered into a multi-faceted agreement with the US DOE, which should improve USEC's competitive situation. DOE will give USEC access to centrifuge technology that the agency developed prior to 1985; and USEC, after carrying out needed research and development, will build a commercial centrifuge enrichment plant at Paducah or Portsmouth. The company must continue to operate the Paducah plant at a minimum of 3.5 million SWU per year until the new plant goes into production - by 2011 if all goes as planned.

Meanwhile, a rival to USEC's planned centrifuge plant is in the offing. Louisiana Energy Services (LES), the partnership that tried unsuccessfully to obtain authorization from the NRC to construct a centrifuge enrichment plant in Homer, Louisiana, in the 1990s, has been reconstituted. The group plans to ask the NRC for a license to construct a gas centrifuge plant, using Urenco's technology, in New Mexico. As of August, 2003, the reconstituted partnership was composed of the foreign companies Urenco and Westinghouse Electric (the latter a 100% subsidiary of British Nuclear Fuels Ltd.) and the US companies Exelon, Entergy, and Duke Energy [Beattie 2003]. Again we are back to the foreign factor.

Fuel fabrication

Fabrication of fuel for civilian reactors, like production of uranium, is today largely in foreign hands. Four plants located in the United States produce civilian fuel. The only one that can be considered a US-directed operation is Global Nuclear Fuel - Americas, which manufactures fuel for boiling water reactors in Wilmington, North Carolina. The owner is Global Nuclear Fuel - General Electric 51%, Hitachi Ltd. 24.5%, and Toshiba Corporation 24.5%. Westinghouse Electric, which produces fuel for pressurized water reactors in Columbia, South Carolina, is now a 100% subsidiary of the British-owned British Nuclear Fuels Ltd (BNFL). (Westinghouse Electric closed a fuel production plant in Hematite, Missouri, in the summer of 2001 following BNFL's purchase of the nuclear fuel operations of Swiss-based ABB, which had owned the plant.) Framatome ANP, which operates a plant in Lynchburg, Virginia that produces fuel assemblies, and a plant in Richland, Washington, that produces pellets and assemblies for boiling water and pressurized water reactors, is owned 66% by the French company Areva and 34% by the German company Siemens. (Prior to the creation of Framatome ANP in 2001, Framatome-Cogéma Fuels, a subsidiary of two French companies, had owned the Lynchburg plant, and Siemens Power Corporation, the Richland plant.)

For two additional plants, the fabrication of fuel for the US Navy is a major project. As would be expected, these plants which are authorized to handle highly enriched uranium, are owned by US companies (BWX Technologies in Lynchburg, Virginia, and Nuclear Fuel

Services in Erwin, Tennessee). They contribute to the commercial fuel chain, notably by blending down highly enriched uranium to produce low-enriched uranium for power reactors.

As noted earlier, the DCS consortium has a contract with DOE to build a plant to produce MOX fuel at DOE's Savanna River site, also to manage the irradiation of the fuel in civilian reactors, and the eventual deactivation of the fuel production plant. The members of the consortium are Duke Engineering Services, Stone and Webster, and Cogéma, Inc., the US subsidiary of the French company Cogéma. Subcontractors include Nuclear Fuel Services (United States), Belgonucléaire (Belgium), and Framatome ANP (France and Germany). Cogéma and Framatome ANP are both subsidiaries of the French firm Areva, created in 2001. DCS will use Cogéma technology for fabrication of the fuel and will manufacture the four lead test assemblies at Cogéma's Cadarache plant in France [Areva 2003], (a plant officially closed in 2003, because it is not earthquake resistant).

Generation of electricity

All of the 104 operable US reactors are wholly or partly owned by US firms. The US near monopoly could vanish over the long term, although the first change will be the in the direction of US ownership. The joint venture AmerGen Energy was formed by the US utility PECO (formerly Philadelphia Electric) and the foreign entity British Energy to buy US nuclear power plants. This venture is today a partnership in which the US utility Exelon (formed by the merger of PECO and Unicom) and the foreign entity British Energy each own 50%. However, the financially-strapped British Energy announced in the fall of 2003 that it will sell its share in Amergen to the US FPL group.

The Atomic Energy Act of 1954, as amended, and the NRC's regulations in 10 CFR 50.38 make foreign entities ineligible to apply for and obtain a license to operate nuclear power plants. The NRC staff evaluates license transfer applications that involve foreign ownership by using the Final Standard Review Plan (SRP) on Foreign Ownership, Control, or Domination, issued September 29, 1999. In addition, the NRC must determine that a license or license transfer "would not be inimical to the common defense and security of the United States." However, apart from a prohibition on 100% ownership by a foreign entity, there is no fixed percentage above which foreign ownership is strictly prohibited.

When AmerGen sought a license transfer that would enable it to operate Three Mile Island, Unit 1, the NRC, "Based on a 'negation action plan' developed pursuant to the SRP to mitigate foreign ownership, control or domination … found that the foreign partner did not control or dominate the safety-related decision making related to the plant. Based on this assessment, the NRC was able to approve AmerGen's purchase of Three Mile Island, Unit 1, as well as subsequent license transfers involving AmerGen," the NRC states [US NRC (nd)].

The NRC states that it has analyzed proposals for license transfers by entities other than AmerGen with some degree of foreign involvement. "As industry consolidation progresses, it is anticipated that there will be additional situations in which foreign organizations seek to acquire

domestic nuclear power plants and domestic utility organizations … *Since 1999, the Commission has developed and submitted proposed legislation that would remove restrictions on foreign ownership*. [italics ours] In March 2002, Senator Domenici introduced S. 472, 'Nuclear Energy Electricity Assurance Act of 2001,' which, among other things would have eliminated the foreign ownership restrictions for nuclear power plants" [US NRC (nd)]. The bill did not pass, but the idea of allowing foreign companies to own US nuclear power plants may return.

The German utility group RWE AG has been interested in investing in US electricity suppliers and has not ruled out nuclear plants [Borsen 2001]. The Canadian Cameco Corp., which already owns uranium mines in the United States, is also among the foreign companies interested in buying US power plants. Cameco has considered investing in idle reactors or completing unfinished facilities in the United States [Financial 2001, Sekhri 2003].

Waste management

In the field of waste management and cleanup, foreign companies regularly compete for and receive contracts. Many of the contracts are for participation in the cleanup of DOE sites, since more cleanup is taking place at these sites than at commercial plants. An example is British Nuclear Fuels Limited's dismantling of the K-25 enrichment plant at Oak Ridge. However, an instance in which a foreign company is involved with work that is civilian and military in nature is the conversion of depleted uranium hexafluoride from the nation's enrichment plants. Framatome ANP Richland Inc., a French-German firm, is the leading member of the consortium, Uranium Disposition Services, that in August 2002 received a contract from DOE to stabilize the material.

A new dimension

A number of times during the 1990s, people raised questions about the possibility of nuclear power plants being targets for terrorist attacks. A government blue ribbon panel pointed to this possibility a full two years before the September 11, 2001. "We should expect conflicts in which adversaries, because of cultural affinities different from our own, will resort to forms and levels of violence shocking to our sensibilities." In fact, during the decade, at least one American nuclear power plant. St. Lucie in Florida was struck by malcontents. Someone(s) poured glue into three lockable switches on the backup control panel on August 14, 1996. This was a room used to gain control of a plant during an emergency. If the reactor could not have been controlled from the main control room, something devastating could have occurred. This incident happened a few weeks after someone had glued locker doors shut at the same plant.

While there were such incidents and some expressed awareness, the companies seemed to rest on their belief that containment vessels could withstand the impact of most aircraft. Few inside or outside the industry talked about the possibility of fully fueled large passenger jets pointed directly nuclear power facilities. A NRC report dated October 2000 studied the effects of accidents at irradiated fuel pools without mentioning the possibility of sabotage or terrorism. In fact, few talked about direct terrorist attacks of any type, perhaps in part from fear that such

talk would precipitate attempts against vulnerable targets. The realization that nuclear plants are potential terrorist targets awaited the next decade, when the prospect of terrorism came to be seen as adding a new dimension to the dangers inherent in the industry. The administration appears not to have absorbed the lesson, however.

Chapter VIII

The Impact of September 11, 2001

Mary Byrd Davis

The events of September 11, 2001, should have put an end to any notion that nuclear reactors are a safe source of energy. As has often been noted in the media, the jet planes that attacked the World Trade Center flew over the Indian Point nuclear power plant on their way to their target. Indian Point is only twenty four miles north of New York City. The attack on the World Trade Center was catastrophic. Had the terrorists, however, chosen to attack Indian Point instead, the result would have been far greater devastation. According to a report by Sandia National Laboratory under contract to the NRC, a core meltdown that released all of the radioactivity in the two reactors could lead to a total of up to 96,000 early fatalities, 308,000 early injuries, 27,000 deaths from cancer, and $558 billion in damages (1980 dollars) [Riccio

2001]. Such facts have apparently not influenced the Bush administration.

Threat of an attack on a nuclear facility

Terrorists view nuclear reactors as possible targets. After the 1993 World Trade Center bombings, terrorists sent a warning to the New York Times that the next attack would be nuclear: "150 suicide soldiers" would attack "nuclear targets." Russian television reported after the 2001 attack on the World Trade Center and Pentagon that "'Our [Russian] security services are warning the United States that what happened on Tuesday is just the beginning, and that the next target of the terrorists will be an American nuclear facility" [quoted by Bivens 2001]. David Kyd, spokesperson for the International Atomic Energy Agency (IAEA) conceded after September 11 that "The West's reliance on electricity, much of it from nuclear sources, is such that a nuclear plant would be a potential weak point for terrorists to pick out" [quoted by Rahir 2001].

The toll from an attack on the reactors at Indian Point would be high, in part because the reactors are near New York City. However, many other US reactors have been built near densely populated areas. For example, Calvert Cliffs is 45 miles from Washington, DC; Limerick is 20 miles outside of Philadelphia; nuclear plants ring Chicago; Monticello and Prairie Island are within 40 miles of Minneapolis-St Paul; and Shearon Harris is 20 miles from North Carolina's research triangle.

Both the IAEA and the US Nuclear Regulatory Commission (NRC), responding to questions from the public, have admitted that plant containment structures were not built to withstand attacks by airliners such as Boeing 757s or 767s [Rahir 2001; Long 2001]. In fact, a report published in 1974 in *Nuclear Safety* found that certain containment structures had no chance of withstanding a direct hit by a plane weighing more than 6.25 tons. The planes that struck the World Trade Center weighed 150 tons [Bivens 2001]. The actions of governments at various levels immediately after September 11 underlined the fact that the terrorist threat is real. Security measures for US plants, though insufficient, included patrols by the National Guard and the Coast Guard, the closing of roads, and a moratorium on flights by general aviation near specified nuclear sites.

An even greater danger than the reactor itself is the pools of water in which utilities store irradiated fuel that they have removed from their reactors. Daniel Hirsch, writing in the *Bulletin of the Atomic Scientists*, states, "A typical nuclear power plant contains within its core about 1,000 times the long-lived radioactivity released by the Hiroshima bomb. The spent fuel pools at nuclear power plants typically contain some multiple of that - several Chernobyls' worth" [Hirsch 2002]. An unclassified study by Brookhaven National Laboratory released in 1997 found that a severe fire in an irradiated fuel pool could make 188 square miles uninhabitable, cause up to 28,000 cancer fatalities, and wreak $59 billion in damages [POGO 2002]. The findings are conservative. Frank von Hippel of Princeton reports that the radioactive plume from a pool fire could contaminate eight to 70 times as much land as that impacted by the Chernobyl accident and cause hundreds of billions of dollars of damage [Process Engineering 2003]. The

NRC report of October 2000 that studied the effects of accidents at spent fuel pools found that a fire resulting from a plane crash could result in the release of 50-100% of the volatile radionuclides in the pool [Large and Schneider, 2000, p. 10]. These would include 20-50 million curies of cesium-137, an isotope which has a thirty-year half life, emits penetrating gamma radiation and "is absorbed in the food chain as if it were potassium" [Alvarez 2002, p. 46].

The pools at US plants are almost always in buildings that are outside the reactor's containment structure. Therefore, the pools have less protection than the reactors themselves. 1) At plants with pressurized water reactors, pools are in fuel handling buildings, "basically standard, industrial-grade buildings (much like K-Mart but without the neon signs)." The fuel pools are usually below ground level. Thus, if they are damaged, the water is less likely to drain out of them than it would be to drain out of above-ground pools. 2) At boiling water reactors, the pools are above ground, inside the building that surrounds the primary reactor containment structure but not within the containment structure itself. The containment structure is made of reinforced concrete and lined with steel; the pool building is only reinforced concrete. Like the pools at pressurized water reactors, the pools at boiling water reactors are designed to resist natural events, but not to withstand "aircraft impacts and explosive forces." Since the boiling water reactor pools are above ground, a crack in the concrete wall or floor of the pool would allow water to drain out.

The pools were designed to hold only about 100 metric tons of fuel each. Utilities planned to transfer fuel after a few years in the pool to a recycling plant or a central repository. No recycling plants or long-term storage facilities have been built. Therefore, the utilities have reracked their pools to allow them to hold additional irradiated fuel. Today the pools are likely to store four to five times more fuel than they were intended to hold. With only 100 metric tons of fuel, a pool could have been safely cooled by air if it lost its water. The pools are safe today only if the water in them is continuously cooled to remove the heat that the densely packed fuel gives off [Process Engineering 2003]. If cooling stops, the water heats up and boils. If the water boils or if it simply drains away, the irradiated fuel assemblies will overheat and either melt or catch fire, with catastrophic consequences [Union of Concerned Scientists 2001].

When fuel storage pools become full, utilities store fuel outside in dry casks sitting on concrete pads. About twenty commercial nuclear plants have dry storage casks. The casks are generally a more secure means of storing fuel than pools, because they rely on passive cooling by radiation and air convection rather than on active cooling by water and pumps [WISE-Paris 2001]. However, at some plants the dry casks are "line-of-sight visible" from open access areas or inside unguarded chain link fences. According to the Union of Concerned Scientists, explosives or weapons that are available on the black market or, in some cases, available legally inside the United States could "cause the casks to be penetrated resulting in the release of large amounts of radiation." [Union of Concerned Scientists 2001]. The Energy Information Administration has removed from its Web site the statistics on the quantities of irradiated fuel at each specific nuclear plant, tacit admission that the stored fuel poses a problem. This was confirmed in a report on Yucca Mountain on CBS's *60 Minutes,* October 26, 2003, when

Secretary of Energy Spencer Abraham was quoted as stating, "We need to find a permanent storage facility" for irradiated fuel. "And without doing that, we'll have not only environmental challenges, but we, I think [sic] it will undermine our energy security and our national security."

Nuclear plants are vulnerable to attacks by numerous means. According to Gordon Thompson of the Institute for Resource and Security Studies in Cambridge, Massachusetts, who has been studying the industry for twenty-five years, the "highest risk mode of attack" is that demonstrated on September 11 - airplanes [Gordon 2003]. Jetliners and smaller planes carrying explosives are both a danger. Whether or not a small plane could penetrate a containment structure, it could penetrate the building housing a storage pool [Kranes 2002]. Targeting a fuel pool would obviously be more difficult than hitting the World Trade Center. However, a commercial airline pilot or a terrorist with some training in a commercial aircraft could do it [Stoller 2003]. A general aviation plane, loaded with explosives, would have "high accuracy of delivery, high expectation of success … and [face] essentially no defense" [Gordon 2003]. The US government has put into effect elaborate safety measures to prevent the hijacking of jetliners. However, according to a study by USA Today, thousands of airports are within 60 miles of plants and "aircraft based at many of these airports are largely unguarded and could reach a nuclear site within minutes" [Stoller 2003]. A study by the NRC itself, concluded before the September 11 attack, stated that half of all airplanes are big enough to penetrate a reinforced concrete wall that is five feet thick [Gordon 2003].

Pools are even vulnerable to commando-style terrorists on the ground. Certain pools are only fifty yards from the double fence around the plant. According to a handbook issued by Sandia National Laboratories, a terrorist could get through the fence line and enter a secured building in under 60 seconds. Based on interviews with security guards and members of military Special Forces, the Project on Government Oversight has stated, "A certain type of explosive, which a terrorist could carry on his back, would allow him to blow a sizeable hole in the reinforced concrete bottom or wall of the spent fuel pool." For above-ground pools, "a certain kind of explosive could even be launched from outside the fence line into the side of the pool" [Brian 2002].

Truck bombs are another possible means of attack. According to a report by Sandia National Laboratory, the truck would not have to enter the site to cause catastrophic damage (at least not given the site boundaries of 2001). A carefully placed truck bomb could destroy essential equipment within a plant from outside a plant's property and thus cause a radiation release. Boats are a source of danger, particularly for plants on large bodies of water. Terrorists might approach a plant by boat with the intent of storming its defenses or simply of clogging the plant's intake valve to cut off the water supply or introducing volatile chemicals into the plant's cooling system [Pasternak 2001].

Even computer networks present a threat, as they could be used by terrorists outside as well as inside the United States. The facts that computer systems at nuclear plants are increasingly being tied into corporate networks and that computers control the electricity grid make them a powerful weapon. The Slammer computer worm (virus) shut down a safety

monitoring system at the Davis-Besse nuclear plant for five hours in January, even though plant personnel thought that a firewall protected the plant's computer system. The worm bypassed the firewall by traveling through the unsecured network of a Davis-Besse contractor and through a line linking that network and Davis-Besse's corporate network. No harm was done, because the plant was offline and also because the work did not affect a redundant analog backup. However, the incident illustrates the danger. The worm also reportedly brought down another utility's critical Supervisory Control and Data Acquisition (SCADA) system [Poulsen 2003].

Instead of targeting nuclear plants directly through computers, terrorists might aim at the electricity grid. Government researchers in the United States, Canada, and the United Kingdom have identified "'back doors' in the digital relays and control room technology that increasingly direct electricity flow in North America. With a few keystrokes, they say, they could shut the computer gear down - or change settings in ways that might trigger cascading blackouts" [Krane 2003]. Nuclear power plants would be among the facilities that would lose power. If a nuclear plant loses electricity from the grid, it turns to backup generators. If they do not function correctly, a catastrophic accident could result. Fortunately in the blackout in the Northeast in August 2003 the reactors that lost power were able to cope safely with the situation but that would not necessarily be the case.

The danger of sabotage from within may be as great as the danger of attack from without. Workers could exploit known vulnerabilities of plants to cause runaway accidents. Moreover, in the past, utilities have hired workers with police records and unstable personalities. For example, a carpenter by the name of Carl Drega worked at three nuclear plants in the Northeast although he had an arrest record and was described in a job reference as "volatile." In 1997, two months after he left the third plant, he shot and killed four people including two state troopers. The plants had not violated regulations by hiring him, an NRC investigation found. A computer programmer, Michael McDermott who worked in the control room at Maine Yankee, was charged with killing seven coworkers at a Massachusetts company after he left the plant. Calvert Cliffs plant employed for eight months an illegal Mexican immigrant with a record of arrest and false identification papers for eight months before they learned his history [Pasternak 2001]. Hiring procedures have been upgraded since 9-11, but have they been improved enough to prevent terrorists from infiltrating the staffs of nuclear plants?

Security at reactor sites is inadequate to defend against attacks from the ground or water, let alone from the air. Utilities usually subcontract for security services with private guard companies. In September 2001, NRC regulations required "nuclear reactor operators to protect against no more than a single insider and/or three external attackers, acting as a single team, wielding no more than hand-held automatic weapons." An attack by such a force was known as the Design Base Threat or DBT. The minimum number of required guards was five. The DBT apparently remained the same for more than a year after September 2001.

As of the September attack, the NRC evaluated security by occasionally staging mock attacks at each plant, under its Operational Safeguards Response Evaluation program (OSRE). However, security guards failed to thwart the attacks in nearly half the tests, despite months of

advance warning that a given test would occur on a certain date [Hirsch 2002]. Moreover, the attackers were not trained in terrorist methods or armed with weapons that terrorists would be likely to use [POGO 2002]. The NRC stopped the tests after September 11, but, according to the General Accounting Office, began pilot force-on-force exercises in 2003 with the intention of designing a new force-on-force testing program. The GAO did not believe that the NRC had specified a date for resumption of formal force-on-force tests [GAO 2003]. Matthew Wald reported in The New York Times that the agency resumed force-on-force tests in 2003 with the intention of testing each plant once every three years rather than once every eight years as previously [Wald September 25, 2003].

After September 11, the NRC recommended to reactor operators that they go to a higher state of alert within the existing security [Hirsch 2002]. In a press release dated February 26, 2002, the NRC announced that it had ordered "nuclear power plants to enhance security." The agency did not give specifics but said that the requirements included "augmented security forces and capabilities", "installation of additional physical barriers…" However, guards at "commercial nuclear power plants across the country" were contacting the Project on Government Oversight (POGO) to express their fears about security at their respective plants.

June 5, 2002, the executive director of POGO testified before the Senate Environment and Public Works Committee that the organization had interviewed guards at 24 nuclear reactors at 13 plants. Guards at only one of four plants were certain that their plant could overcome a terrorist attack. The guards reported that "morale [was] currently very low and that they [were] undermanned, under-equipped, under-trained, and underpaid" [POGO 2002]. In September 2003, the General Accounting Office issued a report "Nuclear Regulatory Commission: Oversight of Security at Nuclear Plants Needs To Be Strengthened" (GAO-03-752), which confirmed many of POGO's findings, including the inadequacy of the NRC's force-on-force tests.

April 29, 2003, in a press release, the NRC finally announced that it had "approved changes to the design basis threat," "the largest reasonable threat against which a regulated private guard force should be expected to defend under existing law." That same day the agency issued an order to that effect including instructions to implement "additional protective actions to protect against sabotage." The NRC refused to make details of even the unclassified portion of the new DBT public [Ramberg 2003]. Therefore, safe energy advocates suspect that the changes are insufficient.

The NRC announced on September 21, 2001 that it would review security at the nation's nuclear plants to find out whether they need to be redesigned to withstand terrorist attacks. To the best of our knowledge, as of October, 2003, the NRC had not made public any results.

The 103 nuclear plants currently generating electricity are not the nation's only targets for nuclear terrorism, moreover. Plants undergoing decommissioning generally have pools of irradiated fuel, and they are likely to be even less well guarded than pools at operating plants. Department of Energy plants that manufacture or have manufactured nuclear materials and

nuclear weapons also are targets as are other fuel cycle facilities. Problems with the security at Department of Energy sites could be the subject of a report in itself.

Another target for terrorists is ships, trains, and trucks transporting nuclear materials. "Mobile Chernobyls" is the name that antinuclear activists have aptly given to the trucks and trains that, if all goes as planned, will carry irradiated fuel to Yucca Mountain. John Large, a nuclear consultant employed by Greenpeace, told Reuters at a United Nations conference on nuclear transport, that current emergency plans can protect shipping casks in accidents but not in an "intelligent" attack. A terrorist could shoot a rocket-propelled grenade at a standard cask for irradiated fuel with disastrous results for the local population [Nuclear 2003].

Because nuclear power plants are centralized sources of energy they contribute to the threat posed by the fragility of the nation's electricity grid. Terrorists could bring down the grid by means of a computer, as mentioned earlier. They could also physically attack a key portion or portions of the grid. The blackouts in the Northeastern United States, in Italy, and in northern Europe in the summer and fall of 2003 give some indication of the problems that an extensive blackout would cause. In the event of a well-aimed terrorist action, the darkness would be unlikely to be as short lived as it was in these cases, however.

Dirty bombs

The detonation of a so-called dirty bomb is another type of threat. A dirty bomb is a bomb made of radioactive materials wrapped around or placed inside conventional explosives. When the conventional explosives are detonated, they scatter the radioactive material over a limited area. Dirty bombs do not involve the fissioning or splitting of atoms as nuclear weapons do, and they do not generate the intense heat and radiation of nuclear weapons.

Radioactive materials that could be used in a dirty bomb are found in such locations as food irradiation installations, laboratories, medical centers, and oil drilling facilities [Federation of American Scientists 2003]. Even in the United States, these materials have not been carefully guarded and monitored, because they are so widespread and because, until September 11, 2001, government officials did not regard them as a serious danger. The NRC reported in May 2002 that US companies had lost track of 1500 radioactive parts since 1996 and had recovered less than half of them. Some were sufficiently radioactive for use in dirty bombs [Gellman 2002]. Radioactive waste from nuclear power plants, which is likely to contain a mixture of radioactive isotopes, is also a candidate for dirty bombs. The possibility that waste will be so used is one of the reasons why low-level waste must be carefully accounted for and disposed of, and disposal sites monitored.

Mohamed ElBaradei, head of the IAEA, has stated that the greatest impact of a dirty bomb would be the "panic and social disruption associated with exposure to radiation, the very purpose of an act of terror" [Charbonneau March 11, 2003]. The actual physical effects would vary with such factors as the radioactive material involved, the amount of material released, and the wind. People living within range of the bomb would be exposed to material in any dust

inhaled during the first passage of the radioactive cloud, and then to material deposited from the dust. Buildings, pavement, and soil would be contaminated. Decontamination methods for buildings might include sandblasting and demolition, with the latter possibly being the only option. "Typically, if decontamination could not reduce the danger of cancer death to about one-in-ten thousand, the EPA would recommend the contaminated area be eventually abandoned" [Federation of American Scientists 2003].

Nuclear weapons

That terrorists or a rogue nation would use against the United States a nuclear weapon composed of fissile material that would sustain a chain reaction is also possible. International nuclear experts take so seriously the possibility that terrorists will build and detonate a nuclear fission bomb that they met in Stockholm in early October to discuss emergency responses should this occur [Charbonneau October 12, 2003].

To make a "conventional" nuclear weapon, 25-35 kg (55-80 pounds) of uranium enriched to 20% or more in uranium-235 [Charbonneau October 12, 2003] or some 5 kg of plutonium-239 [Cochran et al.1984] would be needed. However, a crude nuclear fission device could be made with as little as 2.5-8 kg of uranium at 20% or higher enrichment (the amount would vary with the skill of the fabricators) [Cochran and Paine 1994] or with reactor-grade plutonium [Taylor 94] (plutonium that has been removed from fuel irradiated in a nuclear power plant and that is composed of a variety of plutonium isotopes). Furthermore, experience in building nuclear weapons would not be required. Thus nuclear fission weapons are not beyond the capabilities of determined terrorists. The biggest hurdle for terrorists would be likely to be obtaining the fissile material. This would not be as difficult as it was before the breakup of the Soviet Union. It is improbable although not inconceivable that terrorists would obtain the fissile material in the United States. Russia is a more likely source, since half of Russia's nuclear material is not secured. Russian authorities report that they have broken up hundreds of plots to smuggle fissile material. The largest seizure from smugglers of bomb material occurred in 1994 in Prague, when Czechoslovakian police found 2.72 kilograms of highly enriched uranium in a parked car [Charbonneau October 12, 2003].

Whatever terrorists can do, a nation with a civilian nuclear power program can do better. The United States has good reason to be concerned about the intentions of Iran and North Korea, to speak only of the two nations with nuclear programs most frequently discussed as a threat in late 2003. A nation that is enriching uranium for civilian purposes can also enrich it for military purposes; and a nation that reprocesses the irradiated fuel removed from a civilian reactor will obtain plutonium from the fuel, albeit reactor grade.

And here we return to the US civilian nuclear program. By its existence, the program provides an incentive and a justification for other nations to operate civilian programs. Once a nation has a civilian program, it can, if it chooses, make weapons. Civilian reactors have time and again paved the way for the production of nuclear bombs. Thus, the United States' electricity-generating reactors contribute indirectly if not directly to nuclear proliferation.

A discussion of nuclear proliferation would be a book in itself, and we shall not attempt it here. We should like to point out, however, that a phase out of nuclear power in the United States, in conjunction with cutbacks in the US nuclear weapons arsenal (unilateral if necessary) and an end to plans to develop new nuclear weapons would constitute an important step towards stopping the spread of nuclear materials and nuclear technology.

Steps to take

How can we decrease if not put an end to the threat of nuclear terrorism?

--We should phase out nuclear power. Many thoughtful people rightly regarded the accident at Three Mile Island in 1979 as a reason to do so. The accident, in fact, contributed to a de facto moratorium on contracts for the construction of new reactors, which began before the accident and holds to this day. The risk of an accident remains. Added to this risk and overshadowing it is the threat of nuclear terrorism. Shutting down nuclear reactors would end the danger of a reactor accident and reduce the terrorist risk in three ways. 1) A reactor that has been shut down and that has had its irradiated fuel removed cannot experience a melt-down. Without fuel, a massive release of radiation would not be possible. 2) As indicated above, by ending our own civilian nuclear program, we would remove some of the incentive and also the excuse for other nations, now without nuclear programs, to develop them. 3) We would stop producing irradiated fuel, the disposal of which presents an intractable problem.

--We should face squarely the problem of what to do with the irradiated fuel now in existence. As already discussed, the fuel is unsafe in the pools where most of it is now stored. As far as the health of the current generations of human beings and wildlife is concerned, the fuel would be safer in a well-guarded deep underground repository. However, we do not now have such a repository and will not have one for years to come. Furthermore, transporting the fuel would present a risk and would take years to accomplish. The best option, though far from a perfect solution, may be that advocated by Robert Alvarez and colleagues: storing only the most recently irradiated fuel in pools as was originally intended and transferring the older fuel to casks stored at reactor sites. The change could cost a total of $3.5 - 7.0 billion [Alvarez et al. 2003]. However, much of the cost cannot be avoided in the long term, because the fuel would have to be put into casks if it were to be transported to a storage site like the proposed repository at Yucca Mountain (storage casks can double as transport casks). The casks would obviously have to be thoroughly protected.

--As we have noted already in this section, we must increase protection measures for other nuclear facilities and materials. Simply enforcing the requirements already on the books would make a major difference.

The Response of the Bush Administration

In May 2001 the White House released the National Energy Policy Development Group's National Energy Policy, which, among other things, called for "the expansion of nuclear energy

in the United States as a major component of our national energy policy." Specific recommendations to the White House included supporting legislation to extend the Price-Anderson Act; encouraging the NRC "to relicense existing plants that meet or exceed safety standards"; providing "a deep geologic repository for nuclear waste"; and reexamining policies in order "to allow for research, development and deployment of fuel conditioning methods (such as pyroprocessing)" i.e., reprocessing.

Representatives of the nuclear industry were among the 109 energy industry leaders privileged to meet with Secretary of Energy Spencer Abraham, while he prepared the administration's energy policy. Environmentalists were left out in the cold, except for a chance given to eleven organizations to fax in recommendations on less than forty-eight hours notice [Sierra 2002].

Despite the events of September 11, the administration has not wavered in its announced intention of supporting the nuclear industry. Far from considering a phase out of the nuclear industry, it is continuing to press for the industry's expansion.

As noted in the preceding chapter, the NRC, encouraged by the administration, is renewing the licenses of aging generating plants. President Bush in February 2002 approved Yucca Mountain for the site of a permanent repository for irradiated fuel, a step that encourages the nuclear industry to declare (falsely) that the radioactive waste problem has been solved. Versions of energy legislation passed in 2003 by the House and the Senate respectively contain provisions for research on reprocessing. Furthermore, with the support of the administration, Congress, in February 2002, extended the Price-Anderson Act until December 31, 2003. The nuclear industry would collapse without this act, as it shields plant owners from full liability for the results of accidents. The House Energy Bill (HR 6) would extend the Price-Anderson Act until 2017; the Senate energy bill would extend the act permanently.

The administration June 10, 2002, unveiled a program called Innovations in Nuclear Infrastructure and Education (INIE) to strengthen the nation's fading nuclear education establishment. At that time DOE awarded $5.5 million to four consortia representing fourteen universities. It also announced sixty-five new nuclear engineering grants to universities and seventy-three scholarships and fellowships to students. More funding will be made available in the future, DOE stated.

The administration's Nuclear 2010 program calls for construction of at least one new nuclear plant by 2010. Under the program, the Department of Energy helps companies to prepare and finance applications for early site permits. June 24, 2002 DOE announced that it had "selected three U.S.-based utilities" to participate in the program. Dominion Energy would apply for an early site permit for its North Anna site in Virginia; Entergy for its Grand Gulf site in Mississippi; and Exelon for its Clinton site in Illinois. Each already operates one or more nuclear reactors at its proposed site.

The program takes advantage of the fact that in the Energy Policy Act of 1992 Congress speeded up the licensing process for new nuclear plants. The Nuclear 2010 program is said to be a means of demonstrating and testing the new licensing process for the first time. The Act authorizes the NRC 1) to certify new reactor designs; 2) to preapprove a prospective site for a new nuclear plant; and 3) to grant a combined construction and operating license for a reactor as long as it is to be built according to one of the certified designs on a pre-approved site. The legislation thus does away with post-construction hearings. In the past the NRC issued separate construction and operating permits. Activists were therefore able to slow down and in some instances to halt the process of bringing completed plants on line by raising safety issues that had become apparent during construction. The Act specifies that any safety issues must be litigated before construction begins. These provisions in the Act were bitterly opposed by safe energy activists.

The "early site process" under which the three utilities in the Nuclear 2010 program were to apply pre-approves a site for possible future construction - once issued a permit will be valid for 10 to 20 years. However, an early site process permit does not permit construction nor does it include consideration of a reactor design.

All three utilities filed applications in the fall of 2003. The NRC is expected to spend at least two years reviewing the applications. NRC Commissioner Edward McGaffigan has noted that a reactor would have to be built in three years to meet the 2010 target date. Eugene Grecheck of Dominion, in response, stated that four years but not three years for construction would be "reasonable" [Platt's 2002]. According to DOE, the companies involved will construct "new, safe advanced technology nuclear plants." As of October 2003, the three utilities have not even committed themselves to designs. Moreover, they have not committed themselves to constructing reactors.

In April 2002 DOE announced that it was offering three federal sites for new reactors: the Idaho Engineering and Environmental Laboratory (INEEL), South Carolina's Savannah River Site, and Ohio's Piketon site, location of an enrichment plant. As of October 2003, no company had apparently taken up the offer.

In July 2002, DOE announced that it was making its laboratory in Idaho the "epicenter" of nuclear energy research in the United States. INEEL is scheduled to work on nuclear fuel recycling (i.e., reprocessing) and to lead multinational research and development on Generation IV reactors. These reactors would be more "advanced" than those that the NRC has already certified or is in the process of certifying. According to the Nuclear Energy Institute, "Generation IV's technology roadmap highlights six technologies, including: 1) the high temperature reactor, 2) the supercritical water-cooled reactor, 3) the gas-cooled fast reactor and 4) the lead-cooled fast reactor." DOE plans to have Generation IV designs available for construction between 2010 and 2030. For FY 2003, DOE received $35,328,000 for Nuclear Power 2010 and $7,788,000 for the Generation IV initiative. For FY 2004, DOE requested $34,973,000 for Nuclear Power 2010 and $9,720,000 for Generation IV. The projects constitute the major part of DOE's Nuclear Energy Technology program [Nuclear Energy Institute 2003].

The NRC's reluctance to tighten regulations to prevent nuclear terrorism, discussed earlier in this chapter, is in large measure a result of the administration's pro-nuclear policy. Each tightening of the regulations or of their enforcement can be seen as a tacit admission that the problem of nuclear terrorism is real and pressing.

Chapter IX

Conversion from Nuclear Power

Albert J. Fritsch

A critical question now arises: Can we Americans move away from our dependence on nuclear power for one-fifth of our electricity supply with deliberate speed? We must remember that Germany and Belgium are committed to phasing out their nuclear power facilities. Could we do the same in the United States, but on a more rapid schedule? The answer is "yes." The situation after

September 11, 2001, differs in some respects from the situation at the time of the accident at Three Mile Island. Between 1989 and 2003 we have learned a great deal about how to economize on energy use and about how to generate electricity with renewable resources. We can say with more assurance today than we could then: we could shut down all operating nuclear reactors in relatively short order without having to turn to power plants burning fossil fuels to compensate for the lost electricity.

Energy efficiency/conservation measures alone would allow us to compensate for the electricity currently generated by nuclear reactors. (Strictly speaking, "energy efficiency" means saving energy by using it more efficiently, as in heating to the usual temperature with a furnace that needs less fuel or keeping all the lights on but using energy-saving light bulbs. "Energy conservation" means saving energy by not using it, as in turning down the thermostat or turning off lights. In practice the approaches often overlap or merge.) One way of looking at the energy scenario is to note that to compensate for the loss of nuclear-generated electricity, the United States could simply cut its energy waste. According to the Rocky Mountain Institute, "Just electric efficiency can save four times' nuclear power's output, at one-sixth its operating cost." Speaking of energy in general, G. Tyler Miller, Jr. estimates that American energy waste amounts to 84% of consumption - 41% by degradation of energy quality and 43% "by using fuel-wasting motor vehicles, furnaces and other devices, and by living and working in leaky, poorly insulated and poorly designed buildings." He goes on to write "People in the United States unnecessarily waste as much energy as two-thirds of the world's population consumes" [Miller 1996].

An alternative path to replacing nuclear-generated electricity could be renewable energy. Janet Sawin of World Watch, to indicate the power in renewables, writes, "All U.S. electricity could be provided by wind turbines in just three states - Kansas, North Dakota, and South Dakota - or with solar energy on a plot of land 100 miles square in Nevada." [Sawin 2003, p. 108]. However, wind turbines and solar cells could not be put in place on a massive scale as rapidly as energy efficiency and conservation measures. Therefore during the phase out of nuclear power, energy efficiency and conservation measures could be expected to play the major role. Renewables would supplement them during the phase out and would set us on the path toward replacing the electricity that is generated by fossil fuels at a future date.

In this chapter, we shall initially talk about the general outlines of a phase out. We shall then consider efficiency/conservation measures, first those that could be implemented in the short term and then those that could be used over the long term. Through energy efficiency, large cuts can be made in the use of electricity in industry without any loss in production. For example, changing the layout of pipes to reduce the number of bends in the piping decreases the amount of electricity that needs to be expended in pumping fluid through the pipes. Our emphasis here, however, will be on steps that can be taken to decrease the waste of electricity in individual homes and through community services. We shall then look at the growing use of renewable energy. Finally, we shall discuss motivation for change.

The phase out plan

We concede that during the phase out of nuclear energy, which we advocate for reasons of national security, coal-fired and natural gas-fired power plants would have to continue to operate. Their turn to be replaced will come after all nuclear plants have been shut down and after renewable energy has begun making a substantial contribution to the national energy supply.

In reality we could not expect to put in place instantly all the measures that would allow us to replace nuclear-generated electricity. The phase out would presumably need to take place over a period during which nuclear power facilities, especially those that are faulty, worn out, or near population centers would be shut down quickly, and those with fewer problems are closed later according to a reasonable schedule.

The timetable could be left somewhat flexible so that it would allow for extensions and delays during times of heavy demand. A plant operating during the hottest period of summer could be phased out in the autumn giving the company an additional nine or ten months to implement energy saving measures in that service area. Waivers might have to be granted on a case-by-case basis to certain areas where considerable hardship or economic difficulty may be anticipated, and additional security would have to be given to nuclear power plants in those locations.

All concede that under current conditions for generating electricity some excess electric generation capacity is necessary. Plants have to go offline for servicing; transmission problems arise; weather can create unexpected local emergencies. But strategies for sharing electricity in times of peak demand during hot weather are already in place, and other coping strategies have been developed. Measures taken in California for short-term conservation helped tide utilities through electricity shortages at peak load periods. In case of emergency shortages, measures for conserving electricity include: requiring restriction of non-essential energy use for recreational facilities, park fixtures, and ornamental and advertisement lighting; installing diesel generators for use during times of peak load; requesting voluntary cutbacks or the scheduling of domestic uses such as clothes washing and drying during non-peak times; and instituting rolling blackouts as matters of last resort.

The U.S. Department of Energy would facilitate a national phase out schedule starting with the oldest and most vulnerable nuclear power plants and coming down in a period of about three years to all online reactors. Each individual nuclear power facility would have to develop a phase out plan in coordination with the state utility commission. The plan would include conservation and alternative energy measures that would be implemented in its service district. Since some areas of the country are more dependent on nuclear power than others, the plan would necessarily include movement of electricity between areas.

Not only are Belgium and Germany going through gradual nuclear phase outs, but in the United States the California-based Sacramento Municipal Utility District enacted a phase out plan at the time of the closing of the Rancho Seco nuclear reactor. It hired former TVA director David Freeman and developed some innovative demand-side management (DSM) programs, which can serve as an example to other areas. The Sacramento District incorporates consumer solar production or energy savings into its program and thus defers investment for power plants, transmission and

distribution facilities. It purchased 42,000 energy efficient refrigerators and planted 500,000 shade trees, bought power from four cogeneration industrial facilities, and invested in a wind farm, solar car development, and solar electric systems on rooftops. This one district found that running the program for the consumers was excellent public relations and, besides, reduced the need for a new power plant [Flavin and Lenssen].

Energy conservation/efficiency

The United States has for decades been at the very top of the list in per capita consumption of energy, using half again that of the old Soviet Union, twice that of Germany, and two and half times that of Japan [Durning 1992, p. 53]. These comparisons are behind the constant demand for reducing consumption of materials in this nation. Consumption statistics have held steady over the past three decades, except that the difference between the United States and the Russian successor of the Soviet Union has actually widened due to the latter's industrial production cutbacks.

Many observers, including one of these authors [Fritsch 1974], have pointed out the benefits of curbing of our massive energy wastes through resource conservation. People interested in a variety of conservation measures such as home insulation and more efficient electric appliances have seen the value of energy auditing and subsequent conservation measures in both economic and social terms. The actual resource savings and corresponding reduced pollution of air, water and land are well known to most discerning citizens, though challenging the energy use and waste addiction is not discussed by many conservationists. From an economic standpoint, a growing number of electric utilities see energy conservation as a better investment than utility construction. These companies have forward-looking managers who help encourage and furnish auditing, subsidies and energy saving practices. For them, conservation is a far better investment than more power plants and a viable alternative to them.

Immediate measures

The question when speaking here of nuclear power shutdown is what conservation measures can be implemented rapidly either through utility cooperation, voluntary individual actions, or mandatory regulations to make up for the energy lost by immediate closure of plants. The following six measures could substitute immediately for the lost electricity. All steps could be taken by individuals. The change over to conservation measures does not merely depend on new technology and practices (technology known and currently being implemented), economics (low extra investment costs) or even time (selective “short-term” conservation measures). Rather, the ability to make the change is a matter of individual and political will power.

Domestic electric lighting - a massive savings. The compact fluorescent lamp (CFL) has made immense world sales in the last decade or so. Sales tripled between 1988 and 1993 (from 45 million to 200 million, with Western Europe accounting for twice as many sales as North America [Roodman 1994]. Sales then tripled again. Approximately 600 million units were sold in 2001. Sales of electric bulbs of all types currently exceed ten billion annually, all but a small fraction of these being incandescent bulbs, cheaper and shorter lived than CFLs but less energy efficient.

Nevertheless, as of 2002, an estimated 1.8 billion CFLs were in use, saving 82,000 megawatts of electricity [Scholand 2002].

The earlier versions of the CFL had some difficulties including quite high initial costs and shorter than expected life spans. These bulbs, like other less compact fluorescents, contained small amounts of toxic impurities such as mercury and magnetic ballasts with minute amounts of radioactive materials. However, the quantity of mercury and other heavy metals was quite small compared to the mercury and heavy metals that coal-fired plants would have emitted in generating energy equivalent to that conserved. Consumers can recycle their CFLs to prevent any toxics from contaminating the soil, air, or water [Scholand 2002].

Today mercury content has been reduced to less than 5 milligrams per CFL, and the bulbs with magnetic ballasts are being replaced by less polluting CFLs with electronic ballasts. The electronic ballast types are instant start, do not have the flicker that early magnetic ballast varieties had, and now are available in the size of incandescent bulbs. They may cost more than incandescent bulbs (about $10 each), but they save roughly $50 to $70 per bulb in electricity over their lifetime. Savings are also accrued in replacement costs, since these bulbs last at least 10 times as long as standard incandescent bulbs.

Bulbs should be changed across the board which means closet lights, night, and hallway lights, and "Exit" signs which are often burning all the time, as well as outdoor lighting. Often rooms are over-lighted, and few people complain about it. Homeowners could conduct an audit of lighting in each room to see that family members have adequate lighting in areas where they read or work. Light meters can be acquired from electronics stores or, by mail through electronic or environmental gear magazines. An illuminence of more than 40 foot-candles are required in areas where significant reading takes place.

From what has already been said, about one-half of our potential immediate or short-term energy conservation savings nationwide could result from mandatory use of energy efficient, low-wattage CFL bulbs, which are now commercially available throughout the country. Many utility companies would need little coaxing to see subsidizing such bulbs as a cheaper way of ensuring a steady supply of electricity than building a new power plant.

*Window areas***.** Windows are the areas of greatest heat loss in winter and can be the entrance of sizeable heat gain in summer. Effort should always be made to protect these areas. A variety of strategies are available, including the double panes that are installed on many buildings today. Ability to open and close windows allows for major energy saving, provided minimal care is taken that windows are not conduits for wasted energy. In rooms that are used little or not at all, Styrofoam panels, which work wonders for heat loss reduction, can be placed in window openings. The panels can also be used in other rooms, where they are placed over the glass at night and taken down in the morning. As an alternative, insulating fabric window shades, purchased or made with quilt patterns, can be installed, to be closed at night and opened when the sun shines.

Low-emissivity (Low-E) Window Films. Windows can be treated with glazing

or film that can reflect at least 55% of the heat striking the window (heat from the outside in summer; from the inside in winter) and over 90% of the ultraviolet radiation. Low-E films can reduce glare by 60% but still provide high light transmission. At a cost of about 75 cents a square foot, payback occurs in 12 to 18 months. The films are a fraction of the cost of "Factory high-tech" Low-E windows, which have a payback period as long as 38 years; and the films have a life of about 15 years. The film has the added benefit of making glass shatter-resistant and decreasing the fading of rugs and upholstery by reducing exposure to ultra-violet light. It can be used on most glass.

Insulation and Weatherstripping. Twenty five years ago it was estimated that thirty percent of 80 million residences (24 million) were not insulated at all [Stobaugh and Yergin 1979, p. 212]. While many of these homes have been retrofitted with insulation and some have been torn down, as many as one-tenth of American homes may still not be insulated despite the fact that insulation helps retain heated air in winter and cooled air in summer. Air leaks caused by wind or pressure differences escalate heating bills in cold weather and cooling bills in hot summers. Leakage is likely to occur at sole plates, wall outlets, external doors and windows, fireplaces, and kitchen and bath vents.

Insulation is a good investment, with rapid payback and ultimately immense savings. This has been known for some time, and the more financially savvy businesses and domestic users have curbed electric and other fuel bills by installing more and more insulation. Some renewable energy advocates say that conservation is a bigger determinate of the final utility bill than is the renewable energy source that they promote.

Consumers should determine how much insulation they need, based on the heating zone in which their house is located and "R" value (the measure of resistance of insulation to heat flow). "R" values are stated on every commercial insulation package. In shopping, consider several factors: price, ease of application, the area needing insulation, and availability. Some rock wool, glass fiber, and cellulose fiber must be blown into spaces with special equipment by a professional contractor. This is the method of choice for retrofit insulation of wall and some ceiling space. Unfinished attic floors can be insulated by loose fill which is poured in (rock wool, glass fiber, cellulose, vermiculite or perlite), or by bats (foil side down for barrier effects between insulation and attic floor). Use protective clothing when installing and wash immediately with soap and warm water. Do not hand pack loose insulation. Keep it fluffy. Note that cellulose insulation can be made from old newsprint using a chopping machine and a fire-retardant chemical such as boric acid. Do not use corrosive retardant chemicals. When buying cellulose insulating materials, look for third party testing for safety such as Underwriters Laboratory.

Weatherstrip with commercial metal strip, wood or adhesive-backed foam rubber, rolled vinyl with aluminum channel backing, rubber or neoprene strips, or felt strips. The last are cheap, but not very durable. Local hardware or home-building supply dealers will help in the choice, depending on what one needs to weatherize. Remember to look between door and window frames. Where weatherstripping is not suitable, consider caulking.

Caulking, like weatherstripping, is a good low-cost way to winterize the home or office. It

should be considered for foundation sills, corners formed by siding, along outside water faucets and electrical outlets, at wire and pipe penetration of ceilings, between porches and main parts of the house, at the meeting of chimney or masonry with siding, and where the wall meets the eave at the attic gable end. Caulking comes in all types of cartridges, fillers, rope caulking or glazing compounds. Don't caulk in cold weather, and apply the caulking on clean surfaces. Cut the plastic cover at a slant to allow for better "bead" control in the application. Oil-based caulking materials are the least expensive, but last for only a few years. On the other hand, caulking small and medium cracks with more expensive polysulfide, polyurethane, or silicone will seal the cracks for about two decades. Fillers are used for larger cracks (more than a quarter of an inch) and made from hemp treated with tar, glass fiber, caulking cotton or sponge rubber. The filler is applied before the cartridge caulking is used. Rope caulking is good for temporary jobs around storm windows or air conditioners.

Modular Space Heating and Cooling. A zone heating program, whether a zone is composed of one or several rooms or of an entire floor, is a way of reducing energy needs for space heating and cooling. A part of the savings would be in the form of electricity due to electric appliances, heating units, and heat pumps. So often, whether in the home or work place, the most efficient means of cutting heating (or cooling) costs is to leave the portions of the building that are not or little frequented by people at lower heated (higher cooled) levels. Storage areas, for instance, may not need much heating or cooling. Such modular heating and cooling practices often amount to major savings in energy use. So does installation of air-to-air heat exchangers, which capture heat from air leaving a building and use it to heat air coming into the building.

Where heating can be regulated on a room by room basis, conservation-conscious users need to establish their comfort space. This would immediately result in heating and cooling energy savings. Unfortunately Americans often want higher temperatures indoors in winter than they would tolerate on warm summer days. Conversely, they desire cooler room temperatures in summer than they say they are comfortable with in winter. We cool and heat too much in the hot and cold seasons. After a comfort zone is defined, let it be the yearly norm. If a person is comfortable between 65 and 75 degrees he or she should check temperature on a room thermometer and cool only when the room is above 75 and heat only when it is below 65. Where temperatures in community buildings are controlled by outside mechanisms, encourage residents/ users to locate in areas of the building that are to their preference - the hotter or colder areas. More tolerant persons could expand the breadth of their own personal comfort zone, if they so choose, particularly by wearing warm clothes indoors in the winter. Simply living within one's comfort zone could provide sizeable community building space heating and cooling savings.

Regulating the use of electronics. One of the great sleepers in electricity consumption is not the use of electronics and appliances, but allowing them to remain on at idle when they are not being used. Educational institutions are becoming quite aware of the rising consumption of electricity as each resident student drives up with a U-Haul trailer carrying the computer, stereo, TV, DVD and other electronics along with coffee maker, hair dryer, extra lamps… Computers are not regarded as heavy energy users, but leaving them on when sleeping and out of the room is a traditional practice, especially when residents are not billed according to the amount of electricity they consume. The

same applies to home and office computer users. And the amount of electricity will climb over time. Wasteful and careless practices can drive up electric bills by ten percent without much difficulty. Electricity bills can also be driven up by equipment that consumes electricity when it is switched off in order to cut warm-up time. Unplugging is the simplest answer to this problem.

Habits of students and of others living in group residences may be changed by posted reminders about unplugging electronic devices when not in use. Unplugging is incidentally good insurance against violent electric storms that can overwhelm surge protectors. Timers could be installed to switch lighting and other devices off when not in use. They are standard for lighting in hotel hallways and stairways in France. Motion sensors can also be helpful. Berea College has installed them in a renovated building to prevent lighting of rest rooms when they are not in use. Computerized devices that regulate the amount of heat or other energy according to the time of day are available and can be easily installed. When residents become more aware of energy use, they may become more sensitive to waste and misuse.

Ventilation especially in summer. Modern buildings are often constructed so tightly that there is little infiltration of warm air in summer and cool air in winter. This practice is now known to create some dangerous problems resulting from contaminated indoor air. An estimate that 30% of new or renovated buildings worldwide suffer from "sick building syndrome" may be conservative [Roodman and Lenssen 1995, p. 25]. Ventilation, especially in hot summer months, in air-tight buildings may be a major consideration. Using fans and opening windows (where possible) in the early morning are ways to air out a place. As the temperature begins to rise during the day, close the windows and draw shades to hold in cool air. When assigning rooms or office space, give cooler more airy rooms to those who have more difficulty tolerating heat.

Other cooling suggestions:

--Reduce electricity use inside the building. Install lower wattage lamps. For each 3,000 watts of lights removed about one ton of air conditioning capacity is not needed. Turn off unnecessary inside lights and office machines, minimize use of appliances inside air conditioned areas, stop circulating fans when a room is vacant.

--Reduce heat from cooking. Lower pilot lights. Preheat ovens only if necessary and turn off a few minutes before the required time. Bake or broil several items at a time. It may be possible to cook with a microwave rather than with a range oven or to use outside grilles and solar cookers.

--Reduce the generation of moisture inside the building. Exhaust the moisture from showers, clothes dryers, and cooking. Assure against leaks in exhaust pipes.

--Prevent heat from coming into the building by keeping non-ventilating storm windows closed.

--Open shades and windows on cooler nights.

--Schedule activities according to the temperature. In summer carry out active work earlier in the morning or late at night.

Long-term measures

Longer-term conservation measures are also of great interest, and could result in substantial energy savings. They would take more time to implement than the "short-term" conservation practices sought here. Nevertheless, they must not be forgotten, as the energy saved will sharply lower the need for future power plants of any energy source. The following conservation measures are worth mentioning even though the energy saving will not make a major short-term difference:

Building size is an obvious but often overlooked element in energy conservation. Part of this is due to architect/builder pressure that convinces the consuming public that more and more space is "necessary" for various modern functions. Very few in these influential space advocacy groups promote smaller and more compact buildings that have numerous conservation advantages. Many conservationists who exemplify simple lifestyles are convinced that the largest long-term energy conservation impact would result from halting the escalation in building size. Conventional interior space for residential, educational, commercial, and worship purposes has doubled in the last three decades, greatly increasing demands for heating, cooling, manufacture of building materials and construction.

Building siting is almost as important as building size. Energy savings may accrue as the result of the siting of the building for maximum solar energy use. Low-income residences, *Esperanza del Sol*, constructed in Dallas were solar-oriented and cost an additional annual mortgage payment of thirteen dollars, but annually saved $450 per residence in energy costs [Thayer 1994].

Landscaping has become another major construction factor especially when evergreen trees are used as windshields for winter and deciduous species are planted for shade in summer. Shaded urban landscapes are proving that they significantly lower city temperatures. The planting of trees in proper locations in the yard on the hotter sides of individual homes, offices and other buildings produces the same phenomenon. Trees may start being beneficial after ten to twenty years depending on the species selected and on the climate.

Electric appliances such as refrigerators and ranges are now often manufactured in more energy efficient models and these ratings are posted by federal mandate. Being watchful when purchasing can result in major energy savings, but most people only make such purchases once in a decade or so. It is not expected that this very fruitful practice would have immediate application here.

Cogeneration focuses on utilization of "wasted" heat from electricity-generating plants. The heat, in the form of steam or hot water, is piped to buildings for the purpose of heating. This conservation saving method has been used for years in urban areas of Europe. Since more than half of the energy from conventional power plants is wasted, European cities have been more forward looking than those in America. Denmark is a case in point. By 2002 some 95% of Copenhagen's space heating demands had been met by this method [O'Meara 1999, p. 37].

Efficient public and private transportation is a source of immense energy conservation. The private car has been instrumental in augmenting suburban sprawl. The suburbs, in turn, require greater expenditure of energy for transportation than do urban areas where more public

transportation is used. The private vehicle is a major energy offender, even after years of attempts to bring about the manufacture of energy-efficient vehicles. Few except auto makers anticipated the popularity and the energy inefficiency of sport utility vehicles. The automobile, SUVs, vans and trucks use a large portion of the energy consumed by the transportation sector in the United States. Not much of the energy is in the form of electricity as such. However, gasoline or diesel savings through more energy efficient vehicles are indirectly associated with the challenge at hand, since the oil saved could be refined for other uses such as home heating.

Resource recycling is a major way to conserve energy. Some of the recycled material such as agricultural and forestry wastes are and could continue to be added to the fuel energy mix. Recycling aluminum uses only about a fifth of the energy required in making aluminum from virgin materials. Likewise, many other metals, glass, some plastics, paper products and other portions of the waste stream can be recycled with ease and ingenuity. The ethics of recycling all waste materials - from biomass to used appliances - is currently being widely promoted, but for recycling to reach its full potential it needs friends who will put it on a firm financial footing by giving it tax incentives, new marketing opportunities and subsidies, and governmental help in collecting, sorting and reusing the discarded materials.

Renewable energy

Renewable energy comes in a variety of forms from woods stoves - five million are used each year - to geothermal, tidal, and hydroelectric power, and biomass production. However for the sake of brevity and the need for rapid energy savings we shall focus on two renewable energy sources that may offer the largest return in the shortest possible time, leaving other promising sources to future development and the eventual replacement of all non-renewable energy. As mentioned earlier, the wind potential of just the states of North and South Dakota and Texas would be sufficient to power the current extravagant needs of the United States [Elliott et al. 1991]. Solar shingles on the roofs of all American homes would satisfy our electricity needs in a decentralized manner. Thus wind and solar are our areas of immediate concern.

(Biomass is currently a fuel source, but many environmentalists would prefer to see the biomass materials composted and returned to depleted soil. We do not regard renewable energy derived from corn or other carbohydrate products of agriculture as truly renewable when mechanized farms use gasoline and diesel tractors to sow and harvest the crops, and when other nonrenewable resources are used to ferment, distill and prepare the products. The biomass may be "renewable" in a general way, but the soil and natural fertility expended in growing the fuel crops would be far better spent in preparing food for a hungry world, especially when Americans continue to waste energy.)

Wind power

Wind is the fastest growing energy source in the world, and wind power is now growing exponentially with over 31,100 MW of generating capacity at the end of 2002, an increase of 6868 MW, 28%, over 2001. Total wind power capacity worldwide would now power 7.5 million average

American homes or 16 million average European homes [AWEA-EWEA 2003]. Denmark obtains as large a portion of its electricity from wind as the United States does from nuclear power (20%) [Brown 2003; US DOE 2003]. Germany led the world in generating capacity as of the end of 2002 with 12,000 MW; Spain was second with 4830 MW; the USA, third with 4685 MW; Denmark, fourth with 2880 MW [AWEA-EWEA 2003]. Wind power is now being obtained at prices competitive with the highly subsidized non-renewable energy sources. Including external costs such as damage to the environment, the cost of generating electricity by wind on good wind sites is 4-6 cents per kilowatt hour. This contrasts with 6.3-19.8 cents for coal/lignite and 10.2-14.7 cents for nuclear energy, also counting external costs [Sawin 2003, p. 89]. Denmark may be a relatively small compact nation, with its people close to wind energy sources, but the United States has vast untapped wind potential in almost every region of the nation and near some population centers. Wind power increased 410 MW, 10%, in the United States from 2001 to 2002. Growth would presumably have been faster had it not been for uncertainty about the status of the federal wind energy production tax credit [AWEA-EWEA 2003].

In the 19th century wind devices were decentralized with wind generators on prairie farms pumping water for livestock. Older wind-enthusiasts speak respectfully about Marcellus Jacobs, the father of American wind-generated electricity. The machines he designed and built during a quarter of a century of manufacture developed an excellent reputation for durability, and some still operate. They were generally placed near homes to minimize line losses and were hooked to lead-acid batteries for charging and storing energy for generating electricity. Although satisfactory for the work that had to be done then, the technology of the early American devices and those of the ancient Dutch windmill were notoriously inefficient.

Modern technology has made vast improvements and wind generators found on wind farms have been equipped with single speed, upwind turbines with three fiberglass blades twenty to thirty meters in diameter [Flavin 1994, p. 50]. The average turbine size has gone from 100-200 kilowatts in the early 1990s to 900 kW today. A 900 kW turbine furnishes enough electricity for 540 European homes. Turbines of up to 2000-5000 kW (2-5 megawatts) are being used off shore [Sawin 2003, p. 91] Furthermore, state-of-the-art, aerodynamically engineered devices can run at far lower wind speeds than the nineteenth-century machines (even as low as 5-10 miles per hour).

Denmark and Germany are finding that wind power is furnishing an ever greater share of their electricity needs, and other countries are watching closely. Denmark has been a long time leader in wind energy for some time as one quarter of its industrial energy was coming from wind in the year 1900 [Flavin 1981, p. 9]. The time for wind utilization is arriving in the United States as well, not just in energy-short California where, in the central part of the state, wind is already being put to use. A number of states allow surplus energy produced by the wind generator to be fed back into the system at wholesale rates. This is an advantage for the small- and medium-sized producer as a means of shortening payback periods. A number of American population concentrations are near areas of good wind potential, e.g., San Francisco, Milwaukee, Omaha, Kansas City, Oklahoma City, Dallas/Fort Worth, Minneapolis/St. Paul, and San Jose. Some parts of the United States contain prime wind energy sites that are largely inactive at this time. The Prairie states of North and South Dakota, Nebraska, Kansas, Oklahoma, Texas, Iowa, Minnesota, Missouri, Wyoming,

Montana, and much of Wisconsin and Colorado could meet all their energy needs with safe and non-polluting wind energy without any major difficulty. Add to this the Atlantic coastline as well as California, Oregon, Washington and Alaska. By 2020 some five to ten percent of US electric needs could be met by wind power, if a concerted effort is made using current technology, according to the Wind Energy Association.

Solar applications

British Petroleum Solar reports that if photovoltaic (PV) arrays were installed on every house in Britain, they would supply more electricity than is currently produced by all means for the entire nation. The same has been said for worldwide and American PV installation. G. Tyler Miller, Jr. wrote in 1996, "With an aggressive program starting now, analysis project that solar cells could supply 17% of the world's electricity by 2010 - as much as nuclear power does today - at a lower cost and much lower risk; by 2030 that figure could reach 30% (50% in the United States)." A solarized America would have no need of nuclear or any other power plants for that matter. The technology is there and the system would be totally decentralized as far as production goes.

The rest of the world is ahead of the United States when it comes to solar energy. Japan is the largest producer of PV cells. In 2001 it accounted for 171 megawatts, almost 44 percent of global production. Approximately 120 megawatts of the cells produced were installed in Japan. The United States is the second largest producer with 100.3 megawatts in 2001. However, only 12 megawatts of the 100.3 megawatts were installed in the United States. The production of PV arrays is growing at thirty percent per year worldwide. Production in 2001 was 394 megawatts [Earth Policy Institute 2002]. Installed PVs totaled 1140 megawatts [Sheehan 2002]. Japan has installed 40,000 PV systems; Germany is nearing 100,000 systems. To encourage the use of solar energy in the United States, a Million Solar Roof program, inaugurated by President Clinton in 1997, aims for solar energy systems on one million buildings by the year 2010.

When the educational and research center of one of our authors moved over to net metering through installation of a solar photovoltaic system, the first thing we observed was that immense savings could be made simply by changing the light bulbs to compact fluorescents. The actual observation of energy use on the meter forced us into more primary energy conservation. Solar energy applications work best in buildings inhabited by people who are energy conservation conscious. Thus the two ways of changing the use patterns (conservation and renewables) can easily work hand-in-hand.

Energy savings from installation of solar energy may come about more slowly than savings from conservation methods, not because solar technology is not available, but because PV cell and equipment production would not be able to meet a sudden sharp increase in demand. Again, utilities would be expected to help defray solar costs in domestic and commercial establishments. The increased use of solar shingles would have to be accelerated through subsidies and federal tax write-off. This would be especially important for all new housing and then could be extended to retrofitting of existing housing soon after when more commercially produced shingles become available.

Solar photovoltaic arrays. Photovoltaic "solar cells" that generate electricity directly when exposed to sunlight have been known for decades. The first generation was a single-crystal silicon variety. The second and later generations will be chemical coatings that cost far less and are more versatile. Coatings for tile have been developed which can be put directly on new construction or retrofitted on existing buildings. One may observe those beautiful arrays of shiny multi-colored silicon cells on roofs of homes and other buildings in recent years. These devices allow the sun to bring the electricity directly to us without the need for coal-fired power plants and all their pollution and land disturbance in extracting the fuel. The energy can be generated near where it is used, and stored in batteries for night and rainy days. This saves transmission and generation losses from utility produced electricity.

The federal government's *Million Solar Roofs Program* recognizes that photovoltaic systems need not be a major technological fix for power plants alone - and that the solar program needs to be expanded rapidly. Smaller decentralized efficient solar units are possible, and the technology is proven. The disincentive is that the devices are still expensive due to lack of mass production - 25.6-50.6 cents per kilowatt hour, including external costs. However, costs have dropped 20% for every doubling of capacity or about 5% per year. Therefore, PVs are already the cheapest option for numerous off-grid installations [Sawin 2003, pp. 89-93]. PVs could be used to light homes, road and paths, power appliances, charge solar electric cars, operate traffic signals (especially in remote places), pump water, and run ventilation fans.

Net Metering. When the sun shines down upon us in July, the heat causes air conditioners to operate overtime. As a result, fossil-fueled power plants are often working at peak capacity in the summer. That is the precise time when solar will be able to make its maximum contribution to the utility mix of fuel sources. On the hottest and sunniest days, solar-powered photovoltaics generate plentiful energy to feed back into the system. Owners of domestic PV systems can draw on the electricity that they generate to meet their own needs during sunny days; and, through net metering, can sell any excess power to a utility. At night and on sunless days they can draw their electricity from the utility. Thus they can gain the maximum benefit from solar power without having to invest in expensive battery storage systems. The practice of "net metering" is allowed by state energy commissions in cooperation with electric utility companies in some thirty-six states. Some utilities buy electricity at the wholesale rates that they pay to their outside commercial sources. Others are required by state regulations to buy back at or near consumer purchase prices. Required devices at the PV holder's end, for automatically cutting current flow when the line is down, preserve the health and safety of the maintenance crews working on the utility system.

Solar Hot Water Heating. The most cost-effective and rapidly installed solar application is hot water heating. Photos of the 1904 San Francisco Earthquake show damaged house roofs equipped with solar hot water heaters. About one-tenth of an average household's energy budget is expended on heating water for showers and kitchen uses. The cheapest way to heat domestic water is by the sun. Solar water heating systems may be purchased in active varieties (heating with the sun an enclosed liquid that transfers heat to adjacent water pipes). These active systems are expensive and have not proved as successful as commercial or homemade passive systems. The passive

systems (which heat the water directly in black glass lined metal tanks enclosed in insulated boxes) have no pumps or extra gadgets except a pressure release valve. They should be sized to meet domestic hot water needs, based on the use of water-conservation measures such as shower length and conserving showerheads. They work well with non-solar back-up systems such as instant heating units, if the domestic water demand is low and the water pressure sufficient to allow the flow to move constantly and with suitable force.

Homemade solar water heaters can be built economically and with few prior skills by enclosing a used water tank hooked to a gravity-fed water system. Water is collected in a solar-absorbing black-painted water tank painted black. The enclosure resembles a glass-covered open-sided snug-fitting insulated coffin (made with weather-protected wood). Six-inch fiberglass insulation bats are covered with aluminum flashing to preserve the solar-heated water for use after dark. This homemade solar heater is mounted at the selected location and angled toward the southern sun. Some designers add an insulated door to close over the glassed opening after the sun goes down. In temperate America solar heaters will furnish 100 degree Fahrenheit water for about two-thirds of the year. Normally such devices should be drained in freezing weather. However recent breakthroughs offer systems that function year-round, even in cold Northern regions.

Solar Ornamental and Decorative Lighting. A major energy-saving practice would be to require all ornamental and decorative lighting to come from solar or other renewable energy sources. This would enhance the solar economy and result in considerable energy savings over time. Depending on the amount of light needed, and solar accessibility, systems can cost from $300 to $600 installed. Nothing would stimulate solar energy more than to announce that the decorative Christmas lights are run on solar photovoltaic systems. Even if net metering solar energy is produced during the day and the utility system's other sources are used for night lighting, the arrangement would be a step in the right direction.

Solar Greenhouses and Sunspaces. Solar greenhouses are greenhouses heated by the sun. Sun spaces are domestic areas properly located to receive maximum insolation in winter months. Both structures work better in milder climates and need to be well-insulated, with some sort of heat retaining system such as a water tank or stone. There exists ample literature on where to buy or how to construct free-standing or attached solar greenhouses. The free-standing ones are of course somewhat harder to heat, because they have more exterior surface, but they can be successfully constructed in milder climates by burrowing down and using the earthen surroundings for partial insulation. Lexan and other good plastic and glass glazing can help greatly to retain the heat essential to keeping things from freezing. All structures should face south, but can be turned either slightly east or west with some differences in morning or evening sun benefits.

With good planning and proper choice of plants, the greenhouse and sunspaces may be quite productive without the high cost of heating the structures. These greenhouses act as large permanent cold frames, which provide greens throughout the colder months of the year as well as some seedlings (although they are not a perfect place for all varieties) for the spring planting. Some people use greenhouses year-round. In summer they serve for storage, hearty plant growth or food drying. Others use cold frames in autumn and spring in gardens or vegetable plots to extend the

growing season without the cost of commercial fuel. When properly sited, constructed, insulated and maintained, attached solar greenhouses not only increase food production but also provide a substantial amount of space heating to the adjacent building. One of the authors has directed a center where the 2000 square-foot office space obtained 40% of its heating on sunny days in the winter from a 100 square-foot solar greenhouse on its south side. The greenhouse more than paid for itself in three years.

Motivation

We are not anticipating another 9-11-type disaster that would create a nuclear power plant meltdown in the United States or one of its industrial allies. Perhaps that would trigger a national willingness to make the transition to a non-nuclear energy economy. At the same time we recognize that what is needed is not innovative technology to bring this about, but the simple extension of what is known and what works quite well. We are not even anticipating that the United States be the first nation to move in this direction, for Germany is already on the road and even ahead of us - but with a more conservation-oriented and health-and-safety-conscious attitude. Can we bring the United States to make such a step even though it is feasible, beneficial to the great number of citizens, and a positive step in bringing about homeland security?

Each individual needs to take steps to reduce the nation's dependence on nuclear energy, but many Americans are addicted to wasting energy. One approach to helping them to conquer this addiction would be the concept of sacrifice in time of war. We are now engaged, President Bush says, in a War on Terrorism. In past major wars such as the First World War and the Second World War, conscription, war bonds, and rationing of a wide range of materials (flour, sugar, meat, tires, shoes, gasoline, etc.) brought the country together and impressed on most citizen the necessity of participating in the war effort. Such major conflicts demanded the full cooperative of the concerned citizenry. One way in which citizens could participate in the "war on terrorism" would be to contribute to replacing nuclear energy with conservation and renewables. Such participation need not involve any sacrifice of living standards, but those who habitually waste energy would be likely to regard changing their habits as a sacrifice. The government asks certain individual reservists and armed service personnel to enter harms way. Must we not extend this sense of sacrifice to the entire citizenry and expect all to participate through conservation of resources and especially energy ones?

Participation by individuals will not be sufficient in itself, however. Ideally such policies would be instituted by the national government, but when the national government does not act, state and local governments must become involved. By instituting policies that further the use of renewable energy and also conservation, they not only help accelerate change in their particular geographic areas, but they also provide examples that stimulate other state and local governments to act and that in the long run may help to bring about policy changes at the national level.

Will a nuclear phase out occur in the United States? We are not fortune tellers or false prophets. An optimist may say "yes" and a pessimist will say "no" and leave matters at that. The realist says "maybe, we can succeed with this phase out," with hopes and a commitment to help make a possibility into a reality. As realists we know full well that part of the war on terrorism is a

matter of securing foreign oil fields. We know that in the process of fighting this war, civil liberties may be forced to suffer and may erode in democratic societies. We know that those who are out to make maximized profits will find conservation and renewable energy as anathema. But realists we must be, for we know that mothballing those reactors will make this country more safe - though not totally so. For need we be reminded that on all our folding money is our motto, "In God we Trust?"

Appendix

Nuclear Power Plants by State

(Locations, operators, and owners are drawn from the web site of the Nuclear Energy Institute, www.nei.org, accessed in December 2003. Capacities and expiration dates are taken from the web site of the US Department of Energy's Energy Information Administration, www.eia.doe.gov, accessed in July 2003.)

ALABAMA

Browns Ferry 2 and 3

Type: boiling water reactors from General Electric
Location: near Athens
Operator: Tennessee Valley Authority
Owner: Tennessee Valley Authority
Period of commercial operation: 1975- , 1977- respectively
License expiration: expiration in 2014 and 2016
Capacity: 1113 net MWe each

In 1975 Browns Ferry 1 (1065 net MWe) was heavily damaged in a fire, which burned out electrical controls and necessitated manual shutdown. In 1984 all three reactors were shut down because of safety concerns. Unit 2 restarted in 1991 and Unit 3 restarted in 1995. In counts of US reactors, Browns Ferry 1 is considered an operable plant and the Tennessee Valley Authority plans to bring it back into service in 2007.

Joseph M. Farley 1 and 2

Type: pressurized water reactors from Westinghouse
Location: Houston County
Operator: Southern Company
Owner: Southern Company
Period of commercial operation: 1977- ,1981- respectively
License expiration: 2017 and 2021
Capacity: 833 net MWe, 842 net MWe

ARIZONA

Palo Verde 1, 2, and 3

Type: pressurized water reactors from Combustion Engineering
Location: near Phoenix
Operator: Pinnacle West Capital Corp.

Owner: Pinnacle West Capital Corp. 29%, Salt River Project 17%, Edison International 16%, El Paso Electric 16%, PNM Resources 10%, Southern California Public Power Authority 6%, Los Angeles Department of Water & Power 6%
Period of commercial operation: 1986- , 1986- , 1988-
License expiration: expiration in 2024, 2025, 2027
Capacity: 1243 net MWe, 1243 net MWe, 1247 net MWe

ARKANSAS

Arkansas Nuclear 1 and 2

Type: pressurized water reactors: reactor 1 from Babock and Wilcox; reactor 2 from Combustion Engineering
Location: Russellville
Operator: Entergy Corp.
Owner: Entergy Corp.
Period of commercial operation: 1974- ; 1980-
License expiration: expiration in 2034 and 2018
Capacity: 846 net MWe, 930 net MWe

CALIFORNIA

Diablo Canyon 1 and 2

Type: pressurized water reactors from Westinghouse
Location: Avila Beach
Operator: PG&E Corp.
Owner: PG&E Corp.
Period of commercial operation: 1985- ; 1986-
License expiration: 2021 and 2025
Capacity: 1087 net MWe each

San Onofre 2 and 3

Type: pressurized water reactors from Combustion Engineering
Location: San Clemente
Operator: Edison International
Owner: Edison International 75%, Sempra Energy 20%, Anaheim Public Utilities Dept. 3%, Riverside Public Utilities Dept. 2%
Period of commercial operation: 1983- ; 1984-
License expiration: expiration of both in 2022
Capacity: 1070 net MWe, 1080 net MWe

CONNECTICUT

Millstone 2 and 3

Type: pressurized water reactors: 2 from Combustion Engineering; 3 from Westinghouse
Location: Waterford
Operator: Dominion
Owner: Millstone 2: Dominion 100%; Millstone 3: Dominion 93%, Massachusetts Municipal Wholesale Electric. Co. 5%; Central Vermont Public Service Corp. 2%
Period of commercial operation: 1975- , 1986-
License expiration: 2015, 2025
Capacity: 869 net MWe, 1136 net MWe

FLORIDA

Crystal River 3

Type: pressurized water reactor from Babcock and Wilcox
Location: Crystal River
Operator: Progress Energy, Inc.
Owner: Progress Energy 90%, plus assorted 10%
Period of commercial operation: 1977-
License expiration: 2016
Capacity: 842 net MWe

St. Lucie 1 and 2

Type: pressurized water reactors from Combustion Engineering
Location: Hutchinson Island
Operator: FPL Group, Inc.
Owner: reactor 1, FPL Group, Inc.; reactor 2, FPL Group, Inc. 85%, Florida Municipal Power Agency 9%, Orlando Utilities Commission 6%
Period of commercial operation: 1976- ; 1983-
License expiration: 2 016 and 2023
Licensed Megawatts: 839 net MWe each

Turkey Point 3 and 4

Type: pressurized water reactors from Westinghouse
Location: Florida City
Operator: FPL Group, Inc.
Owner: FPL Group, Inc.
Period of commercial operation: 1972- ; 1973-
License: expiration in 2012 and 2013
Capacity: 693 net MWe each

GEORGIA

Edwin I. Hatch 1 and 2

Type: boiling water reactors from General Electric
Location: Baxley
Operator: Southern Company
Owner: Southern Company 50%, Oglethorpe Power Corp. 30%, Municipal Electric Authority of Georgia 18%, Dalton Water, Gas & Light 2%
Period of commercial operation: 1975- ; 1979-
License expiration: 2034 and 2018
Capacity: 856 net MWe, 870 net MWe

Vogtle 1 and 2

Type: pressurized water reactor from Westinghouse
Location: Waynesboro
Operator: Southern Company
Owner: Southern Company 46%, Oglethorpe Power Corp. 30%, Municipal Electric Authority of Georgia 23%, Dalton Water, Gas & Light 2%
Period of commercial operation: 1987- ; 1989-
License expiration: 2027 and 2029
Capacity: 1148 net MWe; 1149 net MWe

ILLINOIS

Braidwood 1 and 2

Type: pressurized water reactor from Westinghouse
Location: Braidwood
Operator: Exelon Corp.
Owner: Exelon Corp.
Period of commercial operation: 1988- ; 1988-
License: expiration in 2026 and 2027
Capacity: 1185 and 1177 net MWe respectively

Byron 1 and 2

Type: pressurized water reactor from Westinghouse
Location: Byron
Operator: Exelon Corp.
Owner: Exelon Corp.
Period of commercial operation: 1985- ; 1987-
License expiration: expiration in 2024 and 2026

Capacity: 1194 and 1162 MWe respectively

Clinton

Type: boiling water reactor from General Electric
Location: Clinton
Operator: AmerGen Energy Co., LLC
Owner: British Energy PLC 50%, Exelon Corp. 50%
Period of commercial operation: 1987-
License expiration: 2026
Capacity: 1017 MWe

Dresden 2 and 3

Type: boiling water reactor from General Electric
Location: Morris
Operator: Exelon Corp.
Owner: Exelon Corp.
Period of commercial operation: 1970-; 1971-
License expiration: 2009 and 2011
Capacity: 850 and 784 net MWe respectively
Capacity factor in 2000: 99.72% and 92.43%

LaSalle County 1 and 2

Type: boiling water reactor from General Electric
Location: Seneca
Operator: Exelon Corp.
Owner: Exelon Corp.
Period of commercial operation: 1984- ; 1984-
License expiration: 2022 and 2023
Capacity: 1130 net MWe each

Quad Cities 1 and 2

Type: boiling water reactor from General Electric
Location: Cordova
Operator: Exelon Corp.
Owner: Exelon Corp. 75%, MidAmerican Energy Holdings Co. 25%
Period of commercial operation: each 1973-
License: expiration in 2012 each
Capacity: 762 net MWe and 855 net MWe

IOWA

Arnold
Type: boiling water reactor from General Electric
Location: Palo
Operator: Nuclear Management Co.
Owner: Alliant Energy 70%, Central Iowa Power Coop. 20%, Corn Belt Power Coop. 10%
Period of commercial operation: 1975-
License expiration: 2014
Capacity: 520 net MWe

KANSAS

Wolf Creek 1
Type: pressurized water reactor from Westinghouse
Location: Burlington
Operator: Wolf Creek Nuclear Operating Co.
Owner: Great Plains Energy Corp. 47%, Westar Energy, Inc. 47%, Kansas Electric Power Coop, Inc. 6%
Period of commercial operation: 1985-
License expiration: 2025
Capacity: 1170 net MW

LOUISIANA

River Bend 1
Type: boiling water reactor from General Electric
Location: Saint Francisville
Operator: Entergy Corp.
Owner: Entergy Corp.
Period of commercial operation: 1986-
License expiration: 2025
Capacity: 980 MWe

Waterford 3
Type: pressurized water reactor from Combustion Engineering
Location: Taft
Operator: Entergy Corp.
Owner: Entergy Corp.
Period of commercial operation: 1985-
License expiration: 2024
Capacity: 1091 net MWe

MARYLAND

Calvert Cliffs 1 and 2

Type: pressurized water reactor from Combustion Engineering
Location: Lusby
Operator: Constellation Energy Group, Inc.
Owner: Constellation Energy Group, Inc.
Period of commercial operation: 1975-; 1977-
License expiration: 2034 and 2036 (after 20-year extensions)
Capacity: 845 net MWe, 840 net MWe

MASSACHUSETTS

Pilgrim

Type: boiling water reactor from General Electric
Location: Plymouth
Operator: Entergy Corp.
Owner: Entergy Corp.
Period of commercial operation: 1972-
License expiration: 2012
Capacity: 667 net MWe

MICHIGAN

Donald C. Cook 1 and 2

Type: pressurized water reactor from Westinghouse
Location: Bridgman
Operator: American Electric Power Co., Inc.
Owner: American Electric Power Co., Inc.
Period of commercial operation: 1975- ; 1978-
License expiration: 2017, 2017
Capacity: 1000 net MWe, 1060 net MWe

Enrico Fermi 2

Type: boiling water reactor from General Electric
Location: Newport
Operator: DTE Energy Co.
Owner: DTE Energy Co.
Period of commercial operation: 1988-
License expiration: 2025

Capacity: 1111 net MWe

Palisades

Type: pressurized water reactor from Combustion Engineering
Location: Covert
Operator: The Nuclear Management Co., LLC
Owner: CMS Energy Corp.
Period of commercial operation: 1971-
License expiration: 2011
Capacity: 767 net MWe

MINNESOTA

Monticello

Type: boiling water reactor from General Electric
Location: Monticello
Operator: The Nuclear Management Co., LLC
Owner: Xcel Energy Inc.
Period of commercial operation: 1971-
License expiration: 2010
Capacity: 597 net MWe

Prairie Island 1 and 2

Type: pressurized water reactor from Westinghouse
Location: Red Wing
Operator: The Nuclear Management Co., LLC
Owner: Xcel Energy, Inc.
Period of commercial operation: 1973- ; 1974-
License: expiration in 2013 and 2014
Capacity: 525 net MWe, 524 net MWe

MISSISSIPPI

Grand Gulf 1

Type: boiling water reactor from General Electric
Location: Port Gibson
Operator: Entergy Corp.
Owner: System Energy Resources, Inc. 90%; South Mississippi Electric Power Assoc. 10%
Period of commercial operation: 1985-
License expiration: 2024
Capacity: 1231 net MWe

MISSOURI

Callaway

Type: pressurized water reactor from Westinghouse
Location: Fulton
Operator: Amaren Corp.
Owner: Ameren Corp.
Period of commercial operation: 1984-
License: expiration in 2024
Capacity: 1143 net MWe

NEBRASKA

Cooper

Type: boiling water reactor from General Electric
Location: Brownsville
Operator: Nebraska Public Power District
Owner: Nebraska Public Power District
Period of commercial operation: 1974-
License expiration: 2014
Capacity: 758 net MWe

Fort Calhoun

Type: pressurized water reactor from Combustion Engineering
Location: Fort Calhoun
Operator: Omaha Public Power District
Owner: Omaha Public Power District
Period of commercial operation: 1973-
License: expiration in 2013
Capacity: 476 net MWe

NEW HAMPSHIRE

Seabrook

Type: pressurized water reactor from Westinghouse
Location: Portsmouth
Operator: FPL Group, Inc.
Owner: FPL Group, Inc. 88%, Massachusetts Municipal Wholesale Electric Co. 12% *Period of commercial operation*: 1990-

License expiration: 2026
Capacity: 1161 net MWe

NEW JERSEY

Hope Creek 1

Type: boiling water reactor from General Electric
Location: Lower Alloways Creek
Operator: Public Service Enterprise Group
Owner: Public Service Enterprise Group 100%
Period of commercial operation: 1986-
License expiration: 2026
Capacity: 1049 net MWe

Salem 1 and 2

Type: Pressurized water reactor from Westinghouse Corporation
Location: Lower Alloways Creek
Operator: Public Service Enterprise Group, Inc.
Owner: Public Service Enterprise Group, Inc. 57%; Exelon Corp. 43%
Period of commercial operation: 1977- ; 1981-
License expiration: 2016 and 2020
Capacity: 2221 net MWe in total

Oyster Creek

Type: boiling water reactor from General Electric
Location: Lacey Township
Operator: AmerGen Energy Co. LLC
Owner: AmerGen Energy Co. LLC
Period of commercial operation: 1969-
License expiration: 2009
Capacity: 605 net MWe

NEW YORK

James. A. Fitzpatrick

Type: Boiling water reactor from General Electric
Location: Oswego
Operator: Entergy Corp.
Owners: Entergy Corp.
Period of commercial operation: 1975-
License expiration: 2014

Capacity: 840 net MWe

Ginna

Type: two-loop pressurized water reactor from Westinghouse
Location: Rochester
Operator: Energy East Corp.
Owner: Energy East Corp.
Period of commercial operation: 1970-
License: expiration in 2009
Capacity: 498 MWe

Indian Point 2 and 3

Type: Pressurized water reactor from Westinghouse Corporation
Location: Buchanon
Operator: Entergy Corporation
Owner: Entergy Corporation
Period of commercial operation: 1974- ; 1976-
License expiration: 2013 and 2015
Capacity: 971 net MWe, 984 net MWe

Nine Mile Point 1 and 2

Type: boiling water reactor from General Electric
Location: Oswego
Operator: Constellation Energy Group, Inc.
Owner: Nine Mile 1: Constellation Energy Group, Inc. 100%; Nine Mile 2: Constellation Energy Group, Inc. 82%, Long Island Power Authority 18%
Period of commercial operation: 1969- , 1988-
License expiration: 2009 and 2026
Capacity: 621 net MWe, 1135 net MWe

NORTH CAROLINA

Brunswick 1 and 2

Type: boiling water reactor from General Electric
Location: Southport
Operator: Progress Energy Inc.
Owner: Progress Energy 82%, NC Eastern Municipal Power Agency 18%
Period of commercial operation: 1977- ; 1975
License expiration: 2016 and 2014
Capacity: 820 and 811 MWe respectively

McGuire 1 and 2

Type: pressurized water reactor from Westinghouse
Location: Cornelius
Operator: Duke Energy Corp.
Owner: Duke Energy Corp.
Period of commercial operation: 1981-; and 1984-
License expiration: 2021 and 2023 (application for renewal for both filed)
Capacity: 1100 net MWe each

Shearon Harris

Type: pressurized water reactor from Westinghouse
Location: New Hill
Operator: Progress Energy, Inc.
Owner: Progress Energy, Inc. 84%, North Carolina Eastern Municipal Power Agency 16%
Period of commercial operation: 1987-
License expiration: 2026
Capacity: 900 net MWe

OHIO

Davis-Besse

Type: pressurized water reactor from Babcock & Wilcox
Location: Oak Harbor
Operator: FirstEnergy Corp.
Owner: FirstEnergy Corp.
Period of commercial operation: 1978-
License expiration: 2017
Capacity: 873 net MWe

Perry 1

Type: boiling water reactor from General Electric
Location: North Perry
Operator: FirstEnergy Corp.
Owner: FirstEnergy Corp.
Period of commercial operation: 1987-
License expiration: 2026
Capacity: 1238 net MWe

PENNSYLVANIA

Beaver Valley 1 and 2

Type: pressurized water reactor from Westinghouse
Location: Shipping Port
Operator: FirstEnergy Corp.
Owner: FirstEnergy Corp.
Period of commercial operation: 1976- ; 1987-
License expiration: 2016 and 2027
Capacity: 810 and 831 net MWe

Limerick 1 and 2

Type: boiling water reactor from General Electric
Location: Limerick Township
Operator: Exelon Corp.
Owner: Exelon Corp.
Period of commercial operation: 1986- ; 1990-
License expiration: 2024 and 2029
Capacity: 1134 net MWe each

Peach Bottom 2 and 3

Type: boiling water reactor from General Electric
Location: Peach Bottom Township
Operator: Exelon Corp.
Owner: Exelon Corp. 50%, Public Service Enterprise Group, Inc. 50%
Period of commercial operation: 1974-
License expiration: 2013 and 2014 (application for renewal filed)
Capacity: 1093 net MWe each

Susquehanna 1 and 2

Type: boiling water reactor from General Electric
Location: Berwick
Operator: PPL Corp.
Owner: PPL Corp. 90%, Continental Cooperative Services 10%
Period of commercial operation: 1983- ; 1985-
License expiration: 2022 and 2024
Capacity: 1105 net MWe and 1111 net MWe

Three Mile Island 1

Type: pressurized water reactor from Babcock and Wilcox
Location: Londonberry Township
Operator: AmerGen Energy Co. LLC
Owner: Exelon Corp. 50%, British Energy PLC 50%
Period of commercial operation: 1974-
License expiration: 2014

Capacity: 816 net MWe

SOUTH CAROLINA

Catawba 1 and 2

Type: pressurized water reactor from Westinghouse
Location: Clover
Operator: Duke Energy Corp.
Owner: Catawba 1: NC Eastern Electric Membership Corp. 56%; Duke Energy Corp. 25%; Saluda River Electric Coop. 19%; Catawba 2: NC Eastern Municipal Power Agency 75%; Piedmont Municipal Power Agency 25%
Period of commercial operation: 1985- ; 1986-
License: expiration in 2024 and 2026 (application for renewal for both filed)
Capacity: 1129 net MWe each

Oconee 1, 2, and 3

Type: pressurized water reactor from Babcock and Wilcox
Location: Seneca
Operator: Duke Energy Corp.
Owner: Duke Energy Corp.
Period of commercial operation: 1973-, 1974-, 1974-
License: expiration was in 2033, 2033, 2034 (after receipt of 20-year extensions)
Capacity: 846 net MWe each

H.B. Robinson 2

Type: pressurized water reactor from Westinghouse
Location: Hartsville
Operator: Progress Energy, Inc.
Owner: Progress Energy, Inc.
Period of commercial operation: 1971-
License: expiration in 2010
Capacity: 683 net MWe

Virgil C. Summer

Type: pressurized water reactor from Westinghouse
Location: Jenkinsville
Operator: SCANA Co.
Owner: SCANA Corp. 67%, South Carolina Public Service Authority 33%
Period of commercial operation: 1984-
License expiration: 2022
Capacity: 986 net MWe

TENNESSEE

Sequoyah 1 and 2

Type: pressurized water reactor from Westinghouse
Location: Soddy-Daisy
Operator: Tennessee Valley Authority
Owner: Tennessee Valley Authority
Period of commercial operation: 1981- ; 1982-
License: expiration in 2020 and 2021
Capacity: 1126 net MWe and 1125 net MWe

Watts Bar 1

Type: pressurized water reactor from Westinghouse
Location: Spring City
Operator: Tennessee Valley Authority
Owner: Tennessee Valley Authority
Period of commercial operation: 1996-
License: expiration in 2035
Capacity: 1138 net MWe

TEXAS

Comanche Peak 1 and 2

Type: pressurized water reactor from Westinghouse
Location: Somervell County
Operator: TXU Corp.
Owner: TXU Corp.
Period of commercial operation: 1990- ; 1993-
License expiration: 2030 and 2033
Capacity: 1084 and 1124 net MWe respectively

South Texas Project 1 and 2

Type: pressurized water reactor from Westinghouse
Location: Bay City
Operator: CenterPoint Energy, Inc.
Owner: CenterPoint Energy, Inc. 31%, San Antonio Public Service 28%, American Electric Power Co., Inc. 25%, Austin Electric Dept. 16%
Period of commercial operation: 1988- ; 1989-
License expiration: expiration for both in 2027
Capacity: 1264 net MWe and 1265 net MWe

VERMONT

Vermont Yankee

Type: Boiling water reactor from General Electric
Location: Vernon
Operator: Entergy Corp.
Owner: Entergy Corp.
Period of commercial operation: 1972-
License: expiration in 2012
Capacity: 506 net MWe

VIRGINIA

North Anna 1 and 2

Type: pressurized water reactor
Location: Richmond
Operator: Dominion
Owner: Dominion 88%; Old Dominion Electric Coop 12%
Period of commercial operation: 1978 and 1980
License expiration: 2018 and 2020
Capacity: 925 and 917 net MWe respectively

Surry 1 and 2

Type: pressurized water reactor
Location: Newport News
Operator: Dominion
Owner: Dominion
Period of commercial operation: 1972- ; 1973-
License: expiration: 2012 and 2013
Capacity: 810 net MWe and 815 net MWe

WASHINGTON

Columbia (formerly WNP 2)

Type: boiling water reactor (Mark 2) from General Electric
Location: Columbia
Operator: Energy Northwest
Owner: Energy Northwest
Period of commercial operation: 1984-

License expiration: 2023
Capacity: 1108 net MWe

WISCONSIN

Kewaunee

Type: pressurized water reactor from Westinghouse
Location: Carlton Township
Operator: Nuclear Management Co.
Owner: WPS Resources Corp. 59%; Alliant Energy 41%
Period of commercial operation: 1974-
License expiration: 2013
Capacity: 498 net MWe

Point Beach 1 and 2

Type: pressurized water reactor from Westinghouse
Location: Two Creeks
Operator: The Nuclear Management Co., LLC
Owner: Wisconsin Energy Corp.
Period of commercial operation: 1970- ; 1972-
License expiration: 2010 and 2013
Capacity: 505 net MWe and 507 net MWe respectively

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