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# The Wood Energy Challenge: Researching the Potential for New or Expanded Low-Grade Wood Resource Markets in New Hampshire While Facing the Forest Damage Caused by the January, 1998 Ice Storm

*For:*

*N.H. Governor's Office of Energy and Community Services, N.H. Division of Forests & Lands & University of N.H. Cooperative Extension*

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Charles A. Levesque James C. Dammann
June, 1999

This report was commissioned by the New Hampshire Governor's Office of Energy and Community Services, the New Hampshire Division of Forests and Lands, Department of Economic Development, and the University of New Hampshire Cooperative Extension. However, any opinions, findings, conclusions or recommendations expressed herein are those of the authors and do not necessarily reflect the views of these agencies.

## Executive Summary

The purpose of this report is to describe the potential for maintaining or expanding existing low-grade wood markets in New Hampshire and identify, over the next 3-5 years, new markets for low-grade wood. In both cases, the intent is to identify markets or potential markets that draw on low-grade wood resources from the forests of New Hampshire -- not low-grade wood residue material resulting from primary or secondary manufacturing of wood products. The residue market issue is not part of this study. This project was Commissioned by the New Hampshire Governor's Office of Energy and Community Services (GOECS), the New Hampshire Division of Forests and Lands (Division) and the University of New Hampshire Cooperative Extension (UNH) though the findings and recommendations do not necessarily reflect the views of those agencies.

The need for this report results from the concerns that GOECS, the Division and UNH have about the uncertain future of the state's wood energy facilities and the low-grade wood markets they represent. The January, 1998 ice storm caused extensive damage to the forest resources of at least 700,000 acres in the state, causing further need for adequate low-grade wood markets to facilitate salvaging damaged trees in the next 3-5 years.

The research conducted through this project was accomplished under two main categories:

1. low-grade wood market potential
2. timber resource sustainability analysis

After initial scoping and further analysis based on a literature search scan, fourteen major categories of markets were investigated. These markets include:

- Utility plants
- Pellets
- Chip export
- Gasification
- Process heat/co-location
- Biofuels/biochemicals
- Solid wood composites
- Firewood
- Ethanol/methanol
- Animal bedding (sawdust)

- Mulch for landscaping
- Densified logs
- Pulp and paper
- Co-firing at coal fired energy plants

**Likely low grade wood market expansions and new markets in the 1999-2003 period**

Through months of study, investigations in this project have looked carefully at low-grade market opportunities that:

- Can be developed commercially within the next 3-5 years (or are current markets expandable during that period);
- Are markets or potential markets that draw on "green" wood from the forests of New Hampshire, not residues from primary manufacturers;
- Offer substantial market opportunities in the face of a threatened loss of market for 700,000 tons per year of purchased wood chips from New Hampshire sources.

Based on our investigations and research, we believe that no sure substitutes exist for replacement of portions or all of the wood energy markets during the next 1999-2003 period. Despite this, we believe the greatest potential exists for market expansion meeting the three step test described immediately above to include:

- **Green power marketing of the existing wood energy plants**
- **Siting of an Oriented Strand Board plant**
- **Co-firing of Public Service Company of New Hampshire's Bow coal plant with wood**
- **Wood chip exporting**
- **Use of wood sources for production of bio-fuels or bio-chemicals**

In order for these potential markets to be realized, certain public policies must be adopted and certain governmental actions are required. Most significant of these is for the state to develop a policy that encourages use of "green" power sources as a portion of its electricity supply mix and for the Port of Portsmouth to make the investment in wood chip handling equipment for chip export. Other important government actions include active marketing of the state by the Economic Development agency within the Department of Resources and Economic Development as a location to site an Oriented Strand Board plant.

**Timber resource analysis, availability and sustainability**

In order to determine the sustainability of the forests of New Hampshire in light of the potential expanding low-grade wood markets we described in this report, an analysis of the level of timber harvesting relative to the standing volume of timber and growth is needed. We have reviewed the situation and have undertaken a modeling analysis with the assistance of Resource Systems Group under the following scenarios:

- current market structure;
- under a re-structured market where the pending buy-downs of the six wood energy plants are completed; and
- under a re-structured market where the complete shut-down of the six wood energy plants occurs.

***Under all future scenarios, growth exceeds drain by at least 2.4 times and at most, by 3.4 times.*** This suggests ample supply of forest stocking today (with six plants still operating) and, obviously, in the future should the plant buy-downs or buy-outs occur.

A review of two key species considered more heavily harvested shows similar findings. In the worse case year, 1997 (before projections for buy-downs are begun) at the 60% availability level, White Pine growth is at 27.13 million cubic feet statewide while drain is 16.04 million cubic feet – a growth to drain ratio of 1.7:1. For Red Oak the growth is at 14.98 million cubic feet to a 7.21 million cubic feet drain -- a growth to drain ratio of 2.1:1.

**The Wood Energy Challenge: Researching the Potential for New or Expanded Low-Grade Wood Resource Markets in New Hampshire While Facing the Forest Damage Caused by the January, 1998 Ice Storm**

# CONTENTS

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# I. Introduction

I.1 Purpose of Report

Commissioned by the New Hampshire Governor's Office of Energy and Community Services (GOECS), the New Hampshire Division of Forests and Lands (Division) and the University of New Hampshire Cooperative Extension (UNH), the purpose of this report is to outline the potential for maintaining or expanding existing low-grade wood markets in New Hampshire and identifying the potential, over the next 3-5 years, for new markets for low-grade wood. In both cases, the intent is to identify markets or potential markets that draw on low-grade wood resources from the forests of New Hampshire -- not low-grade material that are wood residues resulting from primary or secondary manufacturing of wood products. Although very important, the residue market issue is not part of this study.

The need for this report results from the concerns that GOECS, the Division and UNH have about the uncertain future of the state's wood energy facilities and the low-grade wood markets they represent. GOECS et al believe this issue to be very important for the future of New Hampshire forests because low-grade wood markets are essential to improving forest practices, resulting in higher quality timber resources. The January, 1998 ice storm caused extensive damage to the forest resources of at least 700,000 acres in the state, causing further need for adequate low-grade wood markets to facilitate salvaging damaged trees in the next 3-5 years.

I.2 Basic methodology

To arrive at identification of new or expanded existing low-grade wood markets, this study relied on several research approaches. Understanding the sustainable limits of the forest resource for use in the forest products industry was essential prior to exploring the market opportunities. The recent U.S. Forest Service Forest Inventory Analysis (1997) was the base data source for this analysis which used a modeling process to suggest future sustainability scenarios depending on the possible outcomes of changes underway within the wood energy markets.

The remainder of the research work began with a literature search (see bibliography and Appendix A) to determine if an initial screening of low-grade wood market possibilities missed any significant opportunities to investigate. From there, the team of researchers reviewed previously published and other unpublished reports and papers on the subject and finished by spending the bulk of the research component making personal contacts with researchers, other academicians, government officials, business people in the industry, plant owners and others.

## I.3 Relationship to Forest Industry Task Force

In June, 1997, Governor Jeanne Shaheen and then NH Department of Resources and Economic Development Commissioner Robb Thomson, established the NH Forest Industry Task Force to investigate major issues affecting the industry. One of the goals of the Task Force was to:

> *Develop new markets to replace markets lost by downsizing of wood fired electrical generating plants for underutilized species and lower grades of timber.*

Partly in deference to the research conducted for this report, the Task Force recommended that a committee be formed to specifically focus on the future of the wood energy plants and the potential for alternative profitable markets for low grade wood. This report will likely form the basis for whatever work continues on this subject.

# II. Methods

II.1 Research methodology

The research conducted through this project was accomplished under two main categories:

- low-grade wood market potential
- timber resource sustainability analysis

1) ***Low-grade wood market potential***

The research conducted to explore potential for expanded existing low grade wood markets was of an indirect method. First, a list of potential low-grade wood markets was identified by the research team. Second, a literature search scan was done to verify the original list and add to it. Using the resulting potential markets identified, interviews, document reviews and other indirect methods were used in these analyses.

2) ***Timber resource sustainability analysis***

In order to assure that the forests of New Hampshire will have the ability to be managed sustainably, discussion of expanding low-grade markets for wood products cannot be done without an analysis of the standing timber resource, the growth and mortality of that resource and drain on that resource from wood-using industries. Working with Resource Systems Group, a Stella®5.0 (Object-Oriented Programming) model was created to:

a) analyze the availability and sustainability of current standing timber inventories; and

b) project future timber harvests under a number of scenarios involving changes in the wood energy markets. These scenarios included:

- current market structure;
- under a re-structured market where the pending buy-downs of the six wood energy plants are completed; and
- under a re-structured market where the complete shut-down of the six wood energy plants occurs.

Data were from the 1973, 1983 and, in preliminary form, the 1997 USDA Forest Service Forest Inventory and Analysis (FIA). The most recent data, which forms the basis for the modeling work, was made available on a confidential basis by Philip Bryce, Director of the Division of Forests and Lands. Additional data was obtained from the Forest Service Timber Product Output data source.

To model the change in timber inventories the STELLA programming environment was used. This modeling process enables the creation of a set of mathematical relationships to replicate history (e.g. the change in inventory volumes of White Pine in New Hampshire from 1973 to 1997) or to project future changes in inventories subject to assumptions of inflow and outflow.

# III. Situation Overview

III. 1 Review of wood energy market situation

When New Hampshire's eight large-scale wood energy facilities were sited and built in the 1980s, the economics of energy and the political situation were very different than today, in the late 1990s. With the incentives and mandates provided by the federal Public Utility Regulatory Policy Act (PURPA) and the state Limited Electrical Energy Producer Act (LEEPA), these plants provided markets for 1.5 million tons of whole tree wood chips per year at their peak. Since then, the politics of energy deregulation and the changing economics of energy have resulted in the closure of two of the plants. The potential reductions of power output at all the remaining plants are pending. As of the writing of this report, no additional reductions beyond the two closures have occurred. The current market is approximately 1.2 million tons per year following the closures. Of this, it is estimated that at least 700,000 tons is derived from New Hampshire sources. The primary source of wood chips supplying those six markets is whole tree chips, wood chips made in the woods by loggers chipping trees as part of normal logging operations.

Legislation from the N.H. General Court in 1995 (SB 790) prevented further buy-outs after the Alexandria and Timco plant closures in 1994. In 1998, a very different political situation resulted in legislation (HB 485) that ultimately allows for limited buy-downs and buy-outs beginning in the year 2000, subject to there being competition in the electric industry in the Public Service Company of New Hampshire territory. The original HB 485 filed was considerably harsher relative to plant buy-down/buy-out allowances. The pending buy-down (structured to result in a virtual buy-out) of the Bio-Energy wood energy facility in Hopkinton is not subject to the constraints of HB 485. Should the full allowances for buy-downs and buy-outs take place under the HB 485 scenario, a full 30+% of the current wood energy biomass market could be lost. This represents approximately 360,000 tons per year, roughly equivalent to two of the full-capacity plants still operating.

Even with the limited protections provided by HB 485, the long-term rate orders under which the remaining five plants operate will begin to expire in 2006, continuing to 2013, with little expectation for renewal. Further, nothing is in place to prevent subsequent legislatures from making changes to HB 485. At best, the situation is very tenuous, and all those who depend on the low-grade markets represented by the wood plants are operating with a very unsure future. This affects all business decisions and reaches into critical functions such as financing, so necessary to the capital intensive forest products industry.

Making the reduced low-grade wood markets situation more complex, was the January, 1998 ice storm that damaged timber on at least 700,000 acres. This event has the potential to flood the market with additional low-grade material for many years. Maintaining or increasing low grade markets to accommodate existing and potential supply (within sustainable levels) is of serious concern to the Governor's Office of Energy and Community Services, the Department of Resources and Economic Development and UNH Cooperative Extension. Improving the quality of the timber in the forests in New Hampshire requires that adequate low-grade wood markets exist, particularly following the January, 1998 ice-storm. This is why this study was commissioned.

In addition, The Forest Industry Task Force, created by Governor Shaheen in June of 1997, recommended that a committee be established to low-grade wood markets and their uncertainty due to unstable wood energy markets.

III.2 Review of low-grade market situation

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In addition to the wood energy industry market described above, other large scale low-grade wood markets existing in New Hampshire include:

- manufacturers of paper from wood pulp;
- residential and small commercial firewood users.
- lesser consumers include pallet manufacturers and various other users of lower industrial grade roundwood, primarily softwood.

These markets together represent approximately 1.4 million cords (3.5 million tons) per year of wood.

An important distinction needs to be made to distinguish pulp grade chips from biomass chips. The former are so-called "clean" chips that are free of bark and twigs and are used in paper making. The latter include bark and twigs since the whole tree is used to produce the product. Pulp chips come from sawmill residues and specialty chipping operations that remove bark and branches prior to chipping. Biomass chips result from chipping operations that take whole trees directly from the forest and chip on-site. There is a price differential for the two products with the pulp chips commanding a higher value.

The pulp and paper industry represented by the Berlin, Gorham and Groveton New Hampshire companies of Crown Vantage (soon to be Pulp & Paper of America, Division of American Tissue Corp.) and Wassau Papers/Groveton Paperboard, are the main pulp and paper markets. Additional markets in this industry which draw low-grade wood from New Hampshire include Mead Corporation in Rumford, Maine; S.D. Warren (SAPPI) in Westbrook, Maine (the recent decision to close the pulp plant at this location in early summer 1999 will reduce this market further. The biomass fuel market of 500,000 tons/year at that same facility is currently slated to continue but may also be in jeapordy.); and International Paper in Ticonderoga, New York and Jay, Maine. Several of these operate wood yards in New Hampshire to help supply these mills. Other pulp and paper markets in New York and Maine are represented to a limited extent.

Although the major use of low-grade wood is to make wood pulp for paper making, these mills also use low-grade wood to produce heat, steam and electricity for paper production, and many are anticipated to convert to natural gas for these purposes in the near future, utilizing the gas pipelines being completed (as this report is being written) from Canada. The pulp and paper markets represent approximately 1.1 million cords (2.75 million tons) per year. A more in-depth analysis of these markets and their future potential is found later in this report. It should be noted that pulp and paper markets represent more value added from raw material to finished paper than do energy markets or firewood.

The firewood market has declined significantly since it peaked in the early 1980's, and is unlikely to increase, barring any significant sustained increase in fuel oil prices. This market is primarily a residential market and currently represents approximately 300,000 cords per year based on a recent survey conducted by the Governor's Office of Energy and Community Services.

# IV. Viability of existing and new low-grade wood resource markets in NH in next 3-5 years

The central purpose of this report is to determine the feasibility of continuing or expanding existing low-grade wood markets in New Hampshire and projecting the likeliest candidates for *new* low-grade wood markets. In addition to the importance placed on this issue by the Forest Industry Task Force, the NH Forest Resources Plan makes strong recommendations regarding the importance of these markets for encouraging sound and sustainable forest management.

After initial scoping and further analysis based on a literature search scan conducted by Resource Systems Group, Inc. of Norwich, Vermont[1], fourteen major categories of markets were investigated. These markets include:

- Utility plants
- Pellets
- Chip export
- Gasification
- Process heat/co-location
- Biofuels/biochemicals
- Solid wood composites
- Firewood
- Ethanol/methanol
- Animal bedding (sawdust)
- Mulch for landscaping
- Densified logs
- Pulp and paper
- Co-firing at coal fired energy plants

IV.1 Utility plants

If the existing six wood energy plants could be maintained at their current output capacity over the long-term (past the scheduled end of the rate-orders beginning in 2006), the need for investigating alternative low-grade wood markets would likely be reduced if other markets are maintained. This is not to say that other markets are not needed to adequately encourage sustainable forestry on New Hampshire forest lands. Even with the plants in operation, new markets are desirable, but the need would be greatly reduced if the current markets were secure.

Several alternative scenarios have been investigated to maintain the wood energy markets during the likely buy-down and buy-out scenario contemplated by HB 485 and, more importantly, for the period beginning in 2006 when the rate-orders begin to expire.

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[1] See Appendix A

a. *Stand alone plants*

The current regulatory scheme and political situation for the existing wood energy plants appears to have stabilized for the very immediate period although there is a great likelihood of reductions in the 1.2 million tons per year market (700,000 tons harvested in New Hampshire) in 2000 due to the allowances under HB 485. The reason for the allowed reductions under HB 485 stem from the changed energy cost situation comparing current prices from that in the mid-1980s when the eight plants were sited and permitted. At an average cost of over $.11/kilowatt hour (Kwh) under the existing rate orders compared to a market rate of $.03 to $.035/Kwh, the wood energy plants look unfavorable in today's market. While these high rates were market rate and necessary at the time when the plants were built in order for the developers to obtain financing, they no longer are competitive given the changes in the world energy situation and relatively stable prices for fossil fuels. The rates were based in large part on avoided cost assumptions made at the time the plants were built. Another expert in the field of de-regulation, James Monahan of The Dupont Group in Concord, NH, believes market rates for power after de-regulation will be somewhat higher and could change the economics of the wood plants. He believes market rates will be more in the order of $.04 to $.045/Kwh.

Our knowledge of wood-fired power plants suggests that operating costs are approximately $.05/Kwh including fuel costs. This does not include the fixed costs of debt service or profit needs.

Given the current market prices from other electricity producers in the $.03 - $.035/Kwh price range (or in the future $.04 to $.045/Kwh as James Monahan suggests), particularly given the numerous proposed large-scale combined cycle natural gas plants [2], it seems unlikely that these plants can continue to operate under a completely de-regulated market after the current rate orders expire. This, of course, is given the current price situation based on stable fossil fuel prices. If the economics of these other fuels change, the wood energy plants might become competitive. Ample whole tree chip fuel is available at $ 15-18/green ton today and there is every reason to believe the capability of the whole tree chip producing logging sector will continue as well.

b. *Peaking power*

Electricity demand in the northeast fluctuates with the season. There are times of the year, particularly in excessive heat periods during summer when electrically driven cooling systems cause huge spikes in electricity demand, that require local electricity suppliers to purchase extra electricity production to supply the demand and eliminate brown and blackouts. In New Hampshire, this has occurred every summer this decade with the wood energy plants being asked to produce at maximum capacity (which they did) to assist in meeting demand during those periods. During ultra peak power demand during the summer of 1998 (several days), prices peaked at $7.00/Kwh to garner enough supply to prevent blackouts[3].

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[2] N.H. Public Utilities Commission, July 1998

[3] The Wall Street Journal, July 1998

Using the wood energy plants for peaking power production only would mean utilizing their capacity for several weeks during the year, at most. This approach would be unworkable, especially with plants that still had debt service to retire. Obviously, current plant owners could not afford to operate the plants for only a few weeks during the year, no matter what the price paid for power during those periods. A number of obstacles exist preventing this approach from being in the realm of possibility:

- The owner would be required to have a trained staff on stand-by ready to run the plant;
- A standing staff to keep plant maintenance up would be required on site;
- The long start-up time (24 hours to get plant up to full production capacity from a cold start) is problematic when peak demand situations arise in a matter of hours; and
- Building storage of wood chip fuel on site is problematic because wood fuel tends to break down in time and is prone to spontaneous combustion if chip piles are not rotated and utilized in a timely fashion.

For plants with no debt, it is highly unlikely that a utility or any other entity would purchase the plants as a potential peaking plant. As evidence of this, one need only look at the idle wood energy plant in Alexandria, NH which sold its contract to PSNH in 1994. The plant recently was sold for little more than salvage value in 1997 and has not operated since 1994.

c. *Wood Energy as Green Power*

The advent of electricity deregulation has created the possibility of customer choice in the purchase of electricity. For the first time, there is a potential that with true competition in New Hampshire, electricity customers will be able to choose more environmentally benign sources of electricity. National polls consistently reveal that between 40% and 70% of those sampled say they would pay a premium for environmental protection or renewable energy[4].

However, there is also strong evidence that there is a potentially large gap between what customers say they will do and what they actually do. The difference behind this gap is the difference between opinion polls and other attitudinal surveys and behavior research methods[5]. One such behavioral study found that only 12-15% of customers who had said they would be willing to pay premiums to support renewable energy programs or projects, actually signed up when given the opportunity to do so. Several utilities have done extensive market simulation studies, and even more extensive market tests with their customers, including Public Service Company of Colorado, Wisconsin Public Service and Portland General Electric.

Most of these studies show a consistent pattern of 5-10% of customers willing to pay

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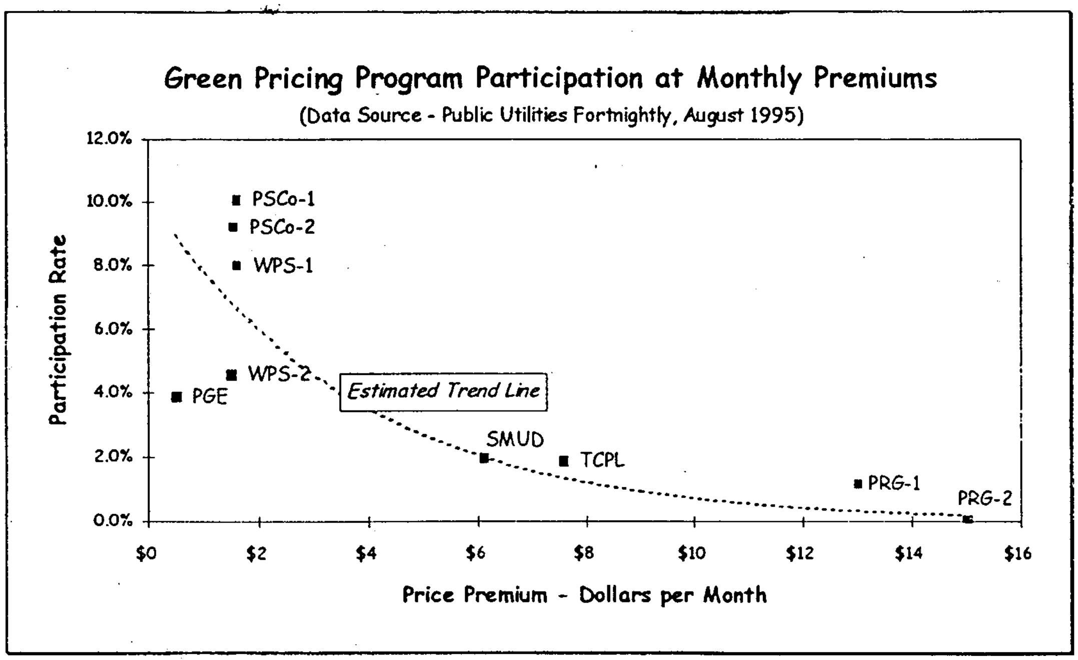
[4] Barbara C. Farhar and Ashley H. Houston, Willingness to Pay for Electricity from Renewable Electricity, National Renewable Energy Laboratory, NREL/TP-460-21216, September 1996.

[5] Holt, Edward A., Green Pricing Resource Guide, US Department of Energy Green Power Resource Guide Chapter 3

a small premium for renewable energy, on the order of between five and ten percent more for their power. *Figure 1* below is an analysis published in the Public Utilities Fortnightly, August 1995. It clearly shows that the higher the price premium, the lower the participation. Participation drops off significantly when customers are asked to contribute more than $2 per month. One utility analyst said up to 10% of customers would pay a premium of up to 10%[6].

**Figure 1**




Many utilities have offered green pricing programs. They have come in three basic categories:

1) **Renewable Energy Contribution Fund**: Utilities offer customers the opportunity to contribute to a fund to be used in the future for a yet to be specified "green" energy project.
2) **Capacity-based Programs:** Customers purchase a fixed block of their electric capacity requirements from renewables.
3) **Energy-based Programs**: Customers purchase a portion or all of their electric energy requirements from renewable energy sources, with the total monthly premium based on the quantity supplied.

Most green pricing programs have been modest in size and scope, by design, with modest financial commitment. While energy suppliers are hesitant to make large, long term capital investments in certain renewables when their research shows an uncertain commitment to renewables by customers and an uncertain customer base due to

[6] Holt, Edward A. and Fang, Jeffrey M., The New Hampshire Retail Competition Pilot Program & The Role of Green Marketing

deregulation, there are good examples of wind and solar investments around the globe. Thus utilities are hesitant to invest large amounts of capital in renewables, whose capital cost is often higher than conventional sources of power, at a time when the market for producing power is becoming increasingly competitive.

There are several important obstacles to the successful marketing of green power generally, and biomass power through the wood energy plants in New Hampshire specifically:

1) **Is it really green?** - There is no universal definition of green power. One definition suggests that green power may be equivalent to renewable power generated from biomass, geothermal, solar, wind, and hydro. A narrower definition would exclude large scale hydro and pumped storage hydro. This difficulty in defining "green" was brought to the forefront during the New Hampshire Retail Competition Pilot Program as several electricity suppliers' claims of "green" and environmentally sensitive sources came into serious question. Some companies were claiming their power to be "green" when in fact some of the sources of the power came from natural gas and nuclear power plants. It is important to assure customers that their "green" purchases are actually contributing to a cleaner environment, that the customer's purchase commitment results in an increase in renewable generation somewhere in the system. Thus the credibility of "green marketing" is dependent on accurate advertising and marketing. If customers are mistrustful of the "green" claims, then the concept of clean energy is severely undermined. To some extent, this appeared to have happened in the New Hampshire experience[7].

To help address these issues in California, the independent, nonprofit Center for Resource Solutions, in concert with power marketers and consumer and environmental stakeholders, launched a voluntary certification and verification program for environmentally preferred electricity products. The "Green-e" logo allows consumers to easily identify products that contain at least 50% renewable electricity content. A northeast group in early 1999 has been discussing including stand-alone biomass energy plants as Green-e certifiable.

2) **Is the market truly competitive**? Generation is currently the only competitive component in the coming deregulated marketplace. In the future, billing, metering and other distribution functions may be competitive in the retail market. In New Hampshire, generation accounts for only about one quarter to one third of the average delivered costs to consumers[8]. Much of the remaining costs are represented in stranded costs[9], the subject of a major legal dispute between Public Service Company of New Hampshire and the State. It is clear that at least a substantial portion of stranded costs in New Hampshire will be recovered through a consumer surcharge, for many years to come. The limited experience from retail pilot programs suggests that consumers are more apt to choose a green power service, even if more expensive, provided they are already receiving some measure of savings to start with. Thus, in the case of New Hampshire, as with most other states considering

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7 ibid

8 Potter, Bob, Unitil Energy Resource, personal communication, 7/29/98

9 investment costs made by the utilities

deregulation, savings from deregulation may not be substantial enough to make green power attractive to consumers. California has dealt with this issue by providing a $.015/Kw rebate for green power purchases to help lower the cost of green power to customers during the stranded cost recovery period.

3) **Is electricity generation from biomass competitive in New Hampshire?** The cost of generating power from wood chip biomass is probably the greatest barrier to its being marketed as "green" power. The cost to **own and operate** a biomass plant is in the $.07 - $.09/Kwh range[10], depending on the size of the plant and the cost of the biomass. This is compared to the $.03 – .04/Kwh[11] it costs to own and operate a combined cycle gas plant. Even lower cost power is often available on the wholesale market, as existing power plants whose capacity is being paid for in a rate base, can sometimes provide power for 2- 3 cents per kilowatt hour. This power is often available from Midwest coal burning plants which are not generating at full capacity. One significant externality resulting from these plants selling their excess power into a deregulating New England market is that increased air emissions from these plants increase New England's air quality problems.

There are several reasons for the higher costs of biomass generated power:

- The capital cost of building the plants are $2,000 per installed kilowatt (kw) versus $600-800 per installed kw for a natural gas plant.
- It takes approximately 20 people to operate a 15-20 Megawatt (MW) wood chip biomass plant, versus about the same number of people to run a 250-500 MW gas plant.
- Combined cycle gas plants are twice as efficient at turning BTU's in the fuel into power as compared with the New Hampshire wood energy plants.

In short, the small percentage of consumers who are willing to pay an extra 10% for environmentally benign power is *not* enough to overcome the fact that biomass power is at least twice as expensive to produce than power from other available sources. For a residential customer making the decision to pay extra for green power, (whose average monthly electricity bill is $ 60), this might mean a $ 5 or $ 6 increase in their bill per month.

It is likely that without some government intervention at some level, it is unreasonable to expect the wood biomass plants in New Hampshire to be able to market their power once their contractual protection is gone, either by buydown/buyout or expiration of rate orders. The beneficial environmental and economic externalities associated with the biomass plants are not taken into account in the marketplace at this time. In addition, the current marketplace is tilted in favor of the utilities whose stranded costs are paid in full through the rate base[12].

While some experts believe prices for wholesale power will increase over time, as

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[10] US Department of Energy, Green Power Guide Chapter 5

[11] George Gantz, Unitil Energy Resource, personal communication, 7/30/98 based on actual costs of plants operating elsewhere

[12] Monahan, James, The Dupont Group, personal communication 5/26/99

utilities are forced to sell their generating plants[13], it seems unlikely that there will be enough of an increase in wholesale rates to allow wood energy plants to operate, particularly considering the large number of low-cost combine-cycle gas plants proposed or under construction in the region.

There are three public policy initiatives that have been tried in other states to attempt to encourage renewables worth mentioning here:

⇒ Establishing a minimum "renewable portfolio standard" (RPS) where an electricity provider must offer a certain minimum percentage of its power for sale from a renewable source. The Pennsylvania Public Utilities Commission is requiring such a standard for the competitive default provider (other states are as well);

⇒ Establishing a surcharge for all customers, the proceeds from which go into a fund for the commercial establishment/maintenance of renewable power sources. Massachusetts has implemented this approach;

⇒ Establishing a rebate for customers who purchase their power from green power providers. This has been implemented in California.

Lastly, following up on the Kyoto agreements relative to global climate change, legislation introduced in Congress in 1998 suggested providing early credits for certain industries involved with sequestering carbon (thereby preventing additional carbon dioxide, a greenhouse gas, from entering the atmosphere). It is suggested that the wood energy industry (using biomass from green forest sources), is that kind of industry. Wood chips for electricity production results from harvesting in forests that will then be regenerated with more forests. These new forests sequester carbon as a result of taking in carbon dioxide through photosynthetic processes.

IV.2 *Wood Pellets*

There is a distinction between densified fiber fuels and wood pellets. Densified fiber fuels is a general class of fuels which include densified logs, briquettes, as well as pellets. Pellets are a small-sized (generally ¼ in. diameter) densified fuel made of formed wood, typically *without any binders*.

The ash content of wood pellets is critical to their success. Pellet stoves are sold to consumers based on their convenience in fuel handling, storage and use. If ash content in a particular pellet fuel is too high, operational problems develop. This was particularly true for the earlier pellet stoves, which would only run well at ash levels below .5%. The technology has improved considerably since then, but ash content in the pellet still remains the critical element for successful operation.

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[13] ibid

Wood pellets became commercially available in the 1970's as a response to rapidly rising oil prices and as an outlet for volumes of sawmill residues, primarily sawdust. Pellets were first manufactured from sawmill residue from large western sawmills. The ash content of these early wood pellets was in the .2 - 5% range[14]. As the market for these residues firmed, in part from the construction of several wood fired power plants in the western states, there was pressure to utilize other feedstocks besides sawmill residues to produce pellets. Pellets made from these other feedstocks were higher in ash content. This caused problems for stoves developed to burn low ash pellets.

Today, residential pellet stoves use a single stage combuster. These combusters run well with ash content below .5%, but begin to experience problems with pellets which have an ash content of much greater than .75%[15]. In fact, lower quality and lower priced pellets with .75 – 1% ash are in less demand than the lower ash, more expensive pellet.[16]. **Unfortunately, it is unlikely that ash contents of less than 1% could be consistently achieved from the use of whole tree chips, which have a significant bark content.** Thus, pellets for the residential market are probably restricted to sawmill waste that has been dried as a feedstock until and unless a residential burner is developed to handle higher ash pellets or until the demand increases enough in order to make debarking and on-site chipping and drying economical.

"Dual stage" combusters, which are able to burn higher ash content pellets, do exist for larger, commercial type installations, but commercial installations are not nearly as prevalent as the residential varieties. The potential growth for these installations is modest at best because of the cost of the wood pellets versus other fuels.

Wood pellets cost substantially more ($80-100 per ton bulk/wholesale and $140-160 per ton bagged/retail) per BTU than oil and gas at current prices. These prices include a raw material cost of about $8-10 per ton for sawmill waste. One ton of pellets is equivalent in BTU value to approximately 100 gallons of heating oil. At $150/ton for bagged wood pellets, oil at $.75/gallon is ½ the cost of wood pellets. Even delivered in bulk, pellets are more expensive than oil on a $/BTU basis, but only slightly. The situation is similar in other parts of the country. Bitteroot Wood Pellets in Darby, Montana, a 6,000 ton per year operation, uses exclusively sawdust and shavings from local sawmill operations. Bitteroot needs dry feedstock materials, 20% or less moisture content, and they don't believe they can produce that economically from directly harvested sources even though they utilize a dryer on some feedstock used now from the mill sources. According to principals for the firm[17], although the operation could produce more pellets if more raw material supply were available from sawmills in the area, they have not chosen to attempt use of other raw materials like green chips. This firm sells its production retail for $ 110/ton bagged, still more expensive than oil per BTU.

Despite this fact, the residential pellet market is growing steadily, at an estimate rate of

[14] The Irland Group, Alternative ChipMarket Scan, Winter 1994, for PSNH

[15] Walker, Steve, personal communication, September, 1998

[16] Cook, Alvin, personal communication, August, 1998

[17] Bitteroot Wood Pellets, personal meeting and conversation, July 18, 1998

10-15% per year[18]. There are three basic reasons for wood pellets' continued popularity at the residential level in spite of the price disadvantage:

1) Green energy -- a small percentage of consumers will pay more for environmentally friendly heat although this fact is not uniformly true throughout the U.S.
2) Some of those people who are inclined to pay more for 'green' heat find pellets more convenient than heating with conventional chunk wood for woodstoves and furnaces.
3) Because pellet stoves are space heaters, some people do save money burning pellets, as the entire residence is not heated nearly as evenly as with a central heating system. In other words, less energy is used with a space heating system versus a central heating system.

Feedstock for wood pellet manufacturers needs to be dried, even if it comes from sawdust sources. For use of green chips, even more drying is needed, further increasing cost of production.

Market penetration in the commercial /industrial sector for wood pellets is very small. The commercial/industrial sector is much less likely to have environmental concerns driving their purchasing decisions. In addition, it is less likely for a commercial establishment to sacrifice the comfort level of their employees and customers. Space heating inevitably sacrifices comfort level. Market penetration of wood pellets in this sector will be severely limited until the price of conventional fuels exceeds that of wood pellets on a BTU basis.

Another downside to the potential for new low-grade wood use as feedstock for pellet manufacturing is that the consumers most likely to enter into purchasing the technology and fuel is the homeowner who already is using chunk firewood for space heating. In other words, the switch by homeowners to pellets from firewood could actually *decrease* the market for low grade wood directly from the forest because pellets will likely be produced with sawmill residues as feedstocks, at least for the next 3-5 years.

The two pellet plants in New England, New England Alternative Fuels in Jaffrey, NH & Catamount Energy, in North Adams, MA, will produce approximately 50,000 tons of pellets in 1999 utilizing some 75,000 tons of wood waste as a feedstock from secondary wood manufacturers and sawmills. This is a significant volume of feedstock but, unfortunately, does not have potential to directly draw green low-grade wood from the forests of New Hampshire.

The utilization of whole tree chips as a feedstock for wood pellets is many years away. There is an adequate supply of low cost secondary wood manufacturer and sawmill waste which is superior (lower ash) to whole tree chips for use as a feedstock. While the residential market is growing, it will take several years to use up the supply of lower cost sawmill waste. In addition, a residential burner capable of burning high ash pellets would

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[18] ibid

need to be developed. In the commercial sector, the substantial price advantage of conventional fuels is the major obstacle.

IV.3 *Chip export*

Exporting wood chips for foreign use in pulp and paper making from the Port of Portsmouth, NH was discussed in several research papers produced in 1994. Lloyd Irland, of The Irland Group in Winthrop, Maine and Dr. Douglas Morris of the University of New Hampshire, looked at the potential to utilize additional low grade wood through satellite yard de-barking and chipping of roundwood in New Hampshire. They analyzed the shipment of clean chips from these potential yards to overseas markets for pulp and paper and the economic implications for New Hampshire of doing so[19]. Irland wrote in 1994:

> *"…Japanese trading companies have developed a worldwide ship supply network to supply the Japanese paper industry's demand for wood fiber…In 1990, as paper and pulp markets worldwide were peaking, buyers from a number of nations began investigating shipments (of wood chips)from the Northeast but interest vanished when paper and pulp prices plunged and the Japanese economy entered a downturn. As the world economy picks up, Japan's chip demand is expected to recover. As this occurs, the fall-off in production in the Pacific Northwest due to restrictions on logging could rejuvenate interest in chip shipments from the Northeast."*

Since that was written, the Japanese economy did indeed go through a major upswing and then, in 1998, a major downturn that saw the yen weaken substantially. In the interim period, in 1996-97, interest in shipping pulp grade wood chips from the Port of Portsmouth nearly resulted in a commercial operation looking to supply upwards of 500,000 green tons per year[20] (NH's wood energy plants currently consume approximately 1.2 million tons per year). The deal fell apart on price. Considering that the northeastern U.S. and Canada are about as far away from the Japanese market as one can get in the world, it is no wonder, for transportation reasons alone, why these export deals are so price sensitive. But that only tells part of the picture because Japan is such a huge importer of wood chips for its pulp and paper industry – 13.9 million bone-dry metric tons annually[21]. In 1997, the Japanese wood chip market held fully *90%* of the entire world trade of wood chips.

Despite the long distance, a Nova Scotia operation began operation in 1997 and, in 1998, shipped five 30,000 ton ship loads to Japan[22]. During the early 1990s, a number of new southern east coast chip exporting operations started up (primarily hardwood) and continue to this day. In 1998, prices paid for those shipping operations increased from $110-111/bone dry unit (ton) to $117-118/bone dry unit[23] or approximately $59/ton green chip delivered equivalent (this is f.o.b. from U.S. ports with 30 day average shipping time to

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[19] The Irland Group, Alternative ChipMarket Scan, Winter 1994, for PSNH & D.E. Morris, Exporting Hardwood Pulp Chips: Economic Impacts to New Hampshire.

[20] Crowell, Peter, personal communcation, July 14, 1998

[21] PaperTree Letter, May 1998

[22] Flynn, Robert, Robert Flynn Associates, personal communication October 10, 1998

[23] ibid

Japan).

Robert Flynn, Principal of Robert Flynn Associates, a Tacoma, Washington-based wood export/import marketing consulting firm, relates that the likelihood of new markets being created for shipping to Japan in the near future is dubious, despite the Nova Scotia entry in 1998. But Flynn admits that more bizarre things can occur in this market. The Japanese pulp and paper wood chip importing actions over the last year defy logic and make little economic sense. Flynn says that normal methods have been for the Japanese to encourage much more exporting chip supply than their market can handle by urging on start-ups (like the near New Hampshire one) with contracts that are just enough to allow for financing of the operators but flexible enough for them to play one exporter off another to get the best price over time. The end result is over-supply and bankruptcy on the part of the most marginal operations.

Add to this the increased wood chip availability from nearby Australian, New Zealand and South American exporters and the situation for New Hampshire or the other northeastern U.S. states does not look favorable today, especially in this economy. The upside is that the huge investment in keeping 100 plus chip transport ships on the waters may keep the chips flowing from all parts of the world even though the economics dictate otherwise.

While it is unlikely that chip exports for paper-making in Japan will work during the immediate future for New Hampshire or possibly within the 3-5 year period envisioned contemplated in this report, should Russian chip supplies to Scandanavian countries dry up, or should a western European market be located, the opportunity might change. Today, the large market for paper making chips in the northern European/Scandanavia area is supplied by seemingly endless, reasonably priced product from Russia's vast forest[24].

In 1998 and even as recently as 1999, serious inquiries have been made at the Port of Portsmouth from parties interested in shipping chips for paper making to Thailand and Spain. The Port has demonstrated its willingness to commit resources to capital improvements to allow for the handling of wood chips at the facility. Up until now, the barrier to export has rested mainly on price. At this time, excess supply and chipping capacity exists to supply offshore exports of chips. Our investigations further indicate that the biggest problem existing today that is preventing export of wood chips for paper making to western Europe is new wood fumigation requirements developed by the European Union to rid cargo of nematodes[25]. Fumigation costs could run as high as $8/green ton (if the technology could be made available at all), an unacceptable cost[26].

IV.4 *Gasification*

1) small and medium-scale commercial

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[24] ibid

[25] Schibels, Scott, Durgin & Crowell, personal communication, 6/3/99

[26] ibid

Increased use of low quality wood for gasification for heat and other uses in small and medium sized commercial establishments has some potential in New Hampshire within the next 3-5 years but the volumes of wood chips likely to be used, even considering modest expansion, are low. The more major concern is that these units, at this time, only use "clean" chips – chips from sawmill residues primarily – and are not capable of using green chips from whole tree operations because of the coarseness associated with chipping the tops of trees (the sticks generated in whole tree chipping create problems for small gasifiers). As such, no level of expansion in this industry will help in the effort to encourage new or expanded markets to draw new whole tree chips or low grade materials from the forests of New Hampshire. While it is theoretically possible that small and medium sized wood gasification units could draw new green low-grade wood from the forests of New Hampshire through the chipping of roundwood versus the chipping of whole trees (this would eliminate the sticks which create a problem for small gasifiers), given the ample supply of the sawmill clean chip source, this will not happen in the near future. Despite this major problem, we further discuss the changes going on in this industry.

Chip Tech, a Vermont-based manufacturer of small to medium sized commercial wood chip gasifiers, has recently shifted its whole marketing emphasis[27]. In the 80s and early 90s, ChipTech focused on schools, other government facilities and hospitals, with some success. Twenty successful conversions from electric or other source heat to wood gasification based heating systems occurred in Vermont schools and other commercial-type facilities such as the police academy and national guard headquarters during that period. No conversions of this kind were completed in New Hampshire. An installation occurred at the Society for the Protection of NH Forests facility in 1996 as part of a demonstration project funded by grants from the NH Governor's Office of Energy and Community Services, the mitigation funds set up when two of the energy plants were bought out by Public Service Company of NH in 1994 and other sources. Chip Tech has installed a gasifier in one school in Pennsylvania in 1996 and one in Massachusetts in 1997. Total "clean" wood chip use at any of these facilities is, at most, approximately 5,000 tons per year, not a large market.

Today, Louis Bravakis, owner of ChipTech, is moving his marketing efforts elsewhere because there are virtually no all-electrically heated schools remaining, the likely candidates in that market. Also, bureaucracy associated with schools, other government facilities and hospitals, all with infrastructures completely unfamiliar with wood fuel, make it expensive and nearly impossible to market the gasifier systems except in a few rare instances where word of mouth and an interested decision maker is present.

Facilities now being converted (some are direct-fire in addition to gasification) are virtually all private sector businesses needing building heat or dry-kiln heat. Most of these converters to wood chip fuel are in the wood products industry. These plants, largely sawmills with kilns in the northern New England region, have a ready fuel supply of suitable grade residues from normal operations, making the switch-over easy. Most of the ownership and maintenance personnel in these firms have ready knowledge and experience

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[27] Louis Brovokis, personal communications July and August, 1998

with wood and are easy converts when the economics and engineering scenarios work for them.

These conversions, Bravakis believes, makes it easier to market to local non-forest products industry firms because one of the difficult selling points -- steady supply and known supplier of wood chip fuel -- is taken care of. Bravakis is using this fact in his efforts to reach non-wood products firms near recently converted wood products-based companies.

Paybacks for the primary manufacturer wood products businesses for heat and kiln use purposes is 1.5 to 4 years. For non-wood manufacturing facilities, payback is estimated at 3 to 7 years. Within those ranges, the determining factor in payback time is dependent on what fuel is being replaced and the capital and installation costs of the new wood-based system along with the local cost of wood chip fuel. Homeowner systems are too small to work efficiently and no manufacturer is making any inroads into this market in the northeast at this time.

This decade, most of the systems converted have been replacing oil as the primary fuel. ChipTech has sold approximately 100 systems, 60 of which have been in wood industry firm facilities. These systems range in cost from $ 200,000 to $ 600,000. Measured in horse power, the usual configuration ranges from 200 to 500 horsepower. A 500 horsepower system, operated year round (not the case if for heat use only), uses 21,900 tons of wood chips in a year. The hospital and school conversions used 200 horsepower systems, which represent approximately 8,700 tons per year of wood chips.

Several variables will affect the likely future conversions of small to medium commercial systems to wood gasification. Wood-based industries will continue to be the most likely converters. Local non-wood commercial facilities needing heat (nearby to wood facilities that have converted), will also be likely candidates for conversion using the ChipTech or similar style hardware systems. The price of oil is a major contributing factor which will, over the next 3-5 year period this study is focused on, determine if non-wood establishments will convert. A sharp rise in oil prices and a readily available very local supply will combine to make more conversions attractive. If oil prices remain stable, conversions will be concentrated in the wood-using industries.

Given the assumption that oil prices will not significantly change over the next 3-5 years, an average of 10 conversions to wood chips might be expected per year in New England. Some of these conversions may be located in New Hampshire, but some or all may not.

While conversions to wood gasification at the small to medium size commercial scale is a positive trend in New Hampshire and elsewhere in New England, the abundant supply of sawmill residues for these units prevent any new gains in low-grade wood markets that may be lost as a result of changes occurring in the wood energy industry.

2) large scale industrial gasification

Until recently, the only commercial wood-based gasification units in operation were for small to medium sized commercial establishments like those discussed in the previous section. In the early 1980s, after successful conversion of an old coal fired plant to wood chips, the Burlington (Vermont) Electric Department built McNeil Station, a stand alone 50 megawatt wood fired electricity generating plant. In 1989, when natural gas became available in the Burlington, Vermont area in large quantities, the plant boiler was modified to allow for full load use of natural gas, which was less expensive than wood chips at that time. In 1999, McNeil has been on a 3-4 year run of operating almost exclusively on wood chips due to cost factors. In April of 1999, natural gas operation costs $ 29.54 per megawatt hour while wood chips are at $ 20.39 per megawatt hour[28] but a more likely wood price in recent months is $ 25.40 per megawatt hour[29]. Given the nature of McNeil as a utility owned generating plant, that is turned on and off depending on the demand and market price of power, wood costs fluctuate. McNeil is 25% efficient when using wood chips as fuel and 31% efficient using natural gas (versus combine-cycle gas plants that are 50% efficient).

In its effort to encourage renewable energy supplies amidst the rapidly evolving deregulating electric utility industry, the US Department of Energy has recently focused on a number of high efficiency power generation technologies that can utilize biomass. One of these technologies is biomass gasification coupled with either a gas turbine in a combined cycle system or a fuel cell.

The Department of Energy chose to invest $ 17 million in the design and testing of such a design using wood chips at the McNeil Station in Burlington. Begun in 1996 and completed in 1998 through a complex arrangement with the process developer and designer Future Energy Resources Corporation (FERCO) using technology developed by Battelle Memorial Laboratories, the facility has been tested during 1998. The process uses a dual fluidized bed system[30] to produce gas of approximately 400 btu per dry standard cubic foot. Dried wood chips are admitted to a gasifier, and are gasified by the addition of silica sand that has been heated to 1,800° F. Steam is admitted to the bottom of the gasifier vessel to fluidize the contents. The product gas/sand/char mixture leaves the gasifier and enters a mechanical centrifugal collector. The product gas leaves the collector and is quenched and scrubbed for final use. The sand and char is separated and enters a second fluidized bed unit called a combustor. Air enters the combustor which burns the char, thereby heating the sand back to 1,800° F so it can be re-used in the process.

As designed, this process yields greater efficiencies than the conventional McNeil Station wood fuel process at 25%. Combining a Battelle Gasifier[31] operating at 70% efficiency with a combined cycle power plant designed for 50% efficiency, yields a plant with a net efficiency of 35%. The McNeil wood boiler, at 25% efficiency for wood that costs $18/ green ton, corresponds to an energy price of $0.0254 of wood fuel/net kilowatt hour

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[28] Kropelin, William, Burlington Electric, personal communication, April 26, 1999

[29] ibid, June 4, 1999

[30] Irving, John M., P.E., "The Biomass Experience at McNeil Generating Station", July, 1998, and presentation to NH Biomass Advisory Committee, Concord, NH July 29, 1998.

[31] Ibid and Farris, Glenn; Irving, John; Paisley, Mark A. & Slack, William, "Commercial Development of the Battelle/FERCO Biomass Gasification Process – Initial Operation of the McNeil Gasifier", October, 1997.

(Kwh). The new gasification system, at $18/green ton at 35% efficiency is approximately $0.0197/net Kwh, more competitive in the current electricity marketplace (exclusive of other operating and capital costs).

At a presentation before the NH Biomass Advisory Committee on July 29, 1998, John Irving, lead engineer for Burlington Electric on the McNeil gasifier project, related the results of the testing on the plant in 1998. While the literature and background papers on the project suggest a major breakthrough for wood gasification, Irving's frank presentation suggested significant additional testing and retrofitting is in order.

A number of problems have surfaced during testing of the project in 1998. These include:

- Cost – The DOE grant for phases one and two (design and build) was $ 17 million. A request is before the DOE for an additional $ 15 million to install the gas turbine and test it. While future installations (beyond the research phase) are expected to cost less, cost will still be significant;
- Air emissions – According to John Irving, the Burlington Electric engineer leading the gasification project, air emissions from the gasifier are expected to be no worse than conventional wood plants and, hopefully, better (according to Irving)[32];
- Chip moisture content – after testing, it was determined that green chips – directly from biomass whole tree harvesting operations, contained too much moisture to allow proper functioning of the system. A chip dryer will need to be installed to bring the moisture content of wood chips to 25% or below;
- Engineering complexity – the design of the McNeil gasification system is very complex relative to a conventional boiler operation. This requires increased on-site engineering and maintenance personnel. A number of problems associated with the silica sand surfaced during testing. Also, the cost of the sand is an additional on-going cost due to the design that may be considered capital in nature in the testing phase but is really an on-going operations cost added to wood chips and other supplies.

Much more testing is needed on the McNeil gasifier, especially with the new turbine yet to be installed, before determinations can be made about the technology's viability in the marketplace. Projected efficiency is 35% (over conventional wood burning plants at 25%) but that has yet to be proven.

John Irving said that he believes the greatest hope today for this technology is to replace very outdated and dirty coal plants in places like India. The forest products industry, particularly pulp and paper plants, may also find this technology appealing, if their feedstock is low quality waste from their own operations. The primary benefit of wood gasification technology at this scale can only be realized if the wood derived fuel is used in a combined cycle plant, not a conventional boiler. Given this fact, it is unlikely that the technology could be applied economically at the New Hampshire plants.

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[32] Irving, John M., P.E, personal communication, May 20, 1999.

## IV.5 *Process heat*

Co-locating users[33] of process heat and steam with the existing wood energy facilities in New Hampshire has been studied extensively over the last five years. Additionally, several near start-ups or prospective start-ups build the knowledge base on this subject.

High determined in 1996 and 1997[34] that of the many potential prospects for co-locating manufacturing facilities at the wood energy plants, three kinds of industries – wood drying kilns, greenhouses and aquaculture – are most suited based on heat/steam needs, cost, and other needs. High does add that the likeliest of these three alternatives, primarily due to its constant load needs (an essential element), is wood dry kilns[35].

Since those analyses were completed, no collocation sitings have occurred. Outside of the two plants closed in 1994, there has been very little incentive for plant owners to seriously consider collocation because, despite the changing legislative climate surrounding the plants with the advent of SB 790 and, more recently, HB 485 (now the law), the current rate-orders still stand and the prospects of fulfilling the negotiated buy-downs are dubious without clear financing sources for PSNH.

Some investigations have occurred and potential collocation sitings explored for both the former Bristol Energy facility in Alexandria and Timco plant in Center Barnstead. In 1995, serious investigations and negotiations were undertaken at the Timco site in an attempt by greenhouse wholesaler Pleasant View Gardens of Loudon to site a major greenhouse expansion at the Center Barnstead site[36]. An ample sized parcel of land was available at the Timco facility to site an expanded Pleasant View Gardens greenhouse operation, and water was available in adequate quantities. Ultimately, the facility was not built because the capital cost of building and connecting to the existing wood energy plant were greater than the greenhouse managers felt they could afford given more conventional alternatives. Pleasant View completed building the new 65,000 square foot facility in Pembroke, NH in the fall of 1998[37]. While initially exploring a stand-alone wood-chip burner for the facility, the owners eventually installed a conventional oil fired boiler to heat the facility citing the high cost of wood chip burner hardware as the reason[38].

A more promising collocation is being explored as this paper is being finalized in the fall of 1998. International Paper owns and operates a substantial sawmill and dry kiln facility in Ossipee, NH, less than one-mile from the Tamworth Pine Tree Power wood energy plant. According to International Paper sources[39], the firm has been negotiating with Pine Tree Power to purchase high temperature steam and water, and to build a pipeline

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[33] co-locating – locating a user of heat and/or steam from wood plant at same site as the producing plants.

[34] High, Colin, *The Feasibility of Collocating Energy-Using Industries at Existing Wood-Fired Power Plants in New Hampshire*, October, 1996 and High, Colin, *The Economic Impacts of Integrating Energy-Using Industries with Existing Wood-Fired Power Plants in New Hampshire, October, 1997*

[35] High, Colin, personal communication, August, 1998 and December, 1998

[36] Bartels, Phil, personal communication 1995 and 1998

[37] Huntington, Jeffrey, Pleasant View Gardens, through Market Bulletin contacts, September, 1998

[38] Weekly Market Bulletin, September 9, 1998

[39] Beck, Paul, personal communication October 21, 1998 and November 19, 1998.

system to carry these products to the kiln site at the sawmill facility. Prospects for completing such an arrangement are reasonably good as this wood energy plant's boiler has excess steam capacity. The size of this potential market, however, is not large. Even doubling the current kiln capacity of the IP operation (currently 250,000 board foot capacity) would result in the use of approximately 9,000 tons of wood chips if the kilns were run at capacity 365 days per year[40].

IV.6 *Biofuels/biochemicals*

New technologies are stretching historical thinking on the kinds of products that might be produced from wood. Currently, the technology for using wood or wood-based waste or residues to produce chemicals such as Levulinic acid or fuel additives such as ethanol and methanol, is available. However, no proven free-market examples using production output of these chemicals currently exist.

In 1995, efforts by a private development firm with grant assistance from the Newfound Economic Development Corporation of Bristol, NH sought to build a large-scale ethanol plant at the site of the former Bristol Energy Corp. wood energy plant in Alexandria, NH. The design of the project was to have revived and retro-fitted the wood plant to provide the steam and power needed for the ethanol plant that was proposed for the site immediately adjacent to the power plant. While the technology had never been tested at the scale being proposed, according to officials close to the project, the following all contributed to the failed project:

- The development component was under-funded;
- Local opposition, which manifested itself around the concern for truck traffic and pollution from the proposed plant;
- Cost of raw material sources;
- Lack of capital for construction.

It wasn't clear whether the plant would have used any green wood material as its raw material source for the ethanol plant component . The developers had discussed everything from paper waste and garbage in addition to wood chips as possible feedstock sources. This lack of certainty and the lack of a clear and direct marketing plan to the community resulted in strong local public concern over the project.

An ethanol plant in Washington state integrated with a pulp mill has been in operation since 1945 and an existing corn ethanol plant in Louisiana has begun an operation for converting sugar cane baggasse (which is chemically similar to hardwood) to ethanol. These two plants, however, are special cases and they do not indicate that wood to ethanol is a viable commercial technology at present.

While this failed attempt in New Hampshire shows that ethanol plants using wood as feedstock have potential, the technology has not been proven on a full-scale approach,

[40] Dowd, Russ, personal communication, November, 1998

except using corn as the feedstock.  Should government fuel additive requirements change in the near future, it is possible that a plant as was discussed for the Alexandria site, might be considered once again.

Levulinic Acid, a chemical used as a base compound for production of many other commercial chemicals, has been made from wood-based by-products (primarily paper and pulping waste) at a pilot research plant in New York by BioFine, Inc. Principals from Pen Cor, an environmental projects developer, are currently investigating sites in New England with the goal of developing a commercial operation for Levulinic Acid production.  A potential site in Salem, NH is being explored as this report is being written[41]. The site is adjacent to a demolition wood processing site that produces 680 tons of wood demo grinding output per day. According to principals for the development company, a commercial operation requires a minimum of 500 tons of wood-based material per day or approximately 175,000 tons per year.

The developer is also looking into the possibility of using paper sludge from New England paper plants as the feedstock source. The developer also suggests interest in using green wood chips. However, there is a question as to whether the developer would pay market rates for wood chips given the negligible or negative cost (i.e. tipping fee) associated with paper sludge and demolition wood feedstock sources. There does not seem to be sufficient economic arguments that show a plant could operate using exclusively or even a large portion of green wood chips costing $16 per ton.

Should the technology developed at the New York pilot plant be transferable to commercial operations, there is potential for siting a plant in New Hampshire.  It is unclear at this time whether there is true commercial viability and whether or not green wood chips could play a significant role in the feedstock needs of such a facility. However, given the size of such potential markets, it is worth monitoring this progression.

### IV.7 *Solid wood composites*

James Bowyer, Director of the Forest Products Management Development Institute, Department of Wood & Paper Science, University of Minnesota, gave a striking presentation on the future of solid wood products at the 1998 national convention of the Society of American Foresters held in Traverse City, Michigan. Bowyer said that the trends show clearly that we are moving quickly to utilizing more and more low-quality wood substitutes for solid wood materials nationally and internationally. From high quality furniture to dimension structural material, the trend is toward substituting the use of Medium Density Fiber board (MDF) for solid wood products like oak for furniture and Oriented Strand Board (OSB) I-beams for floor joists in residential and commercial construction. He is so convinced of the trend toward use of composite substitutes for solid wood products that he said:

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[41] Kaufman, Andrew, President, Pencor Environmental Ventures, Inc., New York and Maryland, personal communication October 2, 1998

*"I'm not convinced that there will be a market for solid sawn timbers at the end of a 200 year rotation (started now)."*

Dr. David Brooks, USDA Forest Service wood products researcher, said at a recent conference[42] that internationally, to the year 2010, solid wood (lumber) demand is likely to decline to 1990 levels while overall demand for wood products will continue to increase. This is due to the lack of availability of large trees, weight characteristics of solid wood and engineering trends to longer spans for structural material. Internationally, forest products represent about 3 % of the overall trade in the world or between $ 120-130 billion annually. The increase in wood products trade will come in the form of solid wood substitutes.

The Food and Agriculture Organization of the United Nations, in its 1990-2010 projections for forest products use and demand published in 1997 shows that a global increase in wood-based panels (particle board, OSB, waferboard) demand is projected at 1.5% per year to the year 2010. At the same time, paper and paperboard demand is projected to increase at 2.5% per year. The substitution of products – composite board products for lumber; OSB for plywood; structurally engineered joist material for large size dimension lumber – will feed the increase.

As a result of these trends, Dr. Brooks projects, the future quality of logs may be more related to uniformity of fiber rather than the size of the log the wood comes from. This will likely mean demand for forest products will increase for intensively managed forests, and plantations. Given the decline in public timber, in addition to these wood demand characteristics changes, this means increased demand for private timber, generally.

Internationally, another big trend over the last 5 years is that the world is consuming fewer and fewer tropical species such as teak and mahogany and more temperate forest woods (due to environmental pressures resulting from deforestation of tropical forests). An exception to this is the use of eucalyptus from tropical latitude plantations. This use has been growing steadily in the 1990s for use as fiber in the pulp and paper industry.

New Hampshire has an abundance of low-quality trees that could be used to make a variety of solid wood substitutes for these varied uses. These "composites" range from the two mentioned, MDF and OSB, to particle board and secondary manufacturing of these primary products.

1) particle board and MDF

Particle board and MDF processes essentially use "fines" produced from sawmill or other primary wood products manufacturing or wood waste to manufacture a composite board product. While particle board is generally familiar because it has been in the marketplace for so long, it is substantially different from its cousin MDF. Both use residues but the particles in particle board are macro sized as compared to that of MDF. MDF fines (wood bits, chips, sawdust and shavings – all dry) get cooked in a digester and then get fed

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[42] *National and Global Trends in Timber Trade and Policy: Which Issues Really Matter?*, panel at the "Sustaining Northern Forests and Jobs in a Global Economy" conference, October 23, 1998, Bretton Woods, NH

through a pair of grooved steel plates (one rotates very fast) to produce a wood fluff – much like cotton candy. This very uniform material is bonded with resins and pressed to produce a very uniform 4 x 8 foot board that, once cut, can be stained or painted to be used as high-quality outer solid wood in furniture, shelving, molding or the like. It can also be used as a base for veneering. There are 17 MDF plants in the U.S., the nearest ones in New York (1) and Pennsylvania (2)[43].

While the use of MDF is growing rapidly as a substitute for expensive solid wood for finish work, this product does *not* address the need for low quality markets for "green' wood in New Hampshire. First, no MDF plant in operation uses green chips from whole tree harvesting operations or roundwood logs to produce the fines for processing. All of the existing plants use sawmill residues of sawdust, shavings and chips or urban wood demolition fines as raw material. Second, there is little likelihood that existing plants, or a new plant, would utitilize green wood when residues are more than adequate and available at less cost[44]. Siting an MDF plant in New Hampshire would have positive effects on the problem of excess sawmill residues (assuming the supply is adequate), but that is not the focus of this report.

2) Oriented Strand Board (OSB)

Oriented Strand Board is a vastly different product and requires a completely different source of raw material compared with particle board and MDF. OSB uses green logs (directly from forest to mill) as its source of material. Because the material needed is lower quality than that used by sawmills, an OSB plant would be an ideal new market (although it would compete with existing pulpwood markets), to replace low quality wood markets represented by that which may be lost by the wood energy plants.

Sixty-five OSB plants are now operating in the United States and Canada[45]. Forty-five of these are located in the U.S. During 1996, 11 new plants were built to bring North American annual capacity to 19 million cubic meters ($m^3$)[46]. In 1997, four new plants were built. In 1998, two more were built (both in Canada.) This increase in capacity caught up with demand, causing the permanent shutdown of 3 of the older plants due to price reductions for OSB product in the marketplace. In May of 1999 MacMillan Bloedel broke ground for a new plant in Saskatchewan. Figure 2 shows that capacity is still ahead of production in North America.

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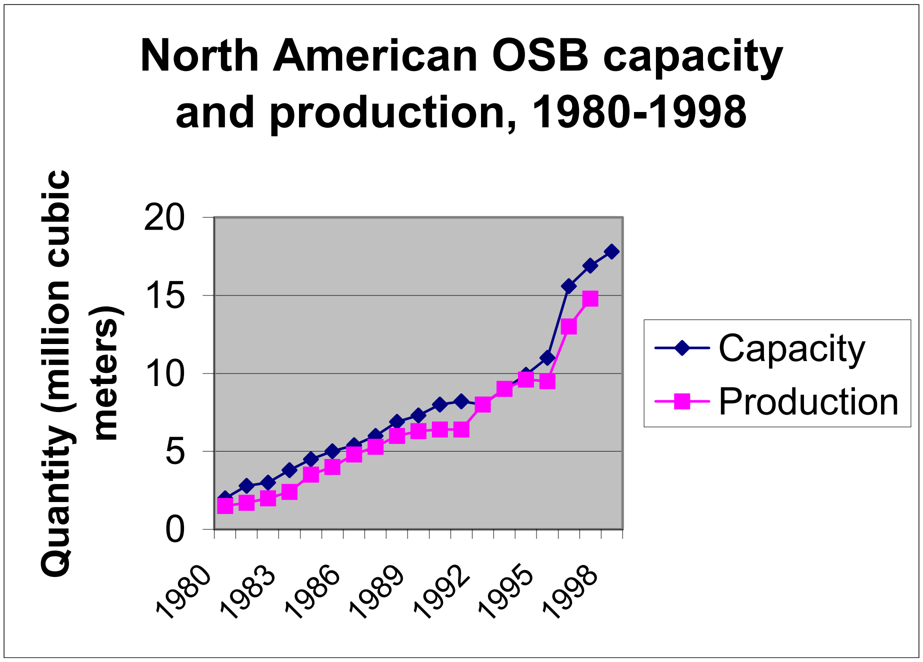
43 McKeever, Tim and Spelter, Henry, Wood-Based Panel Plant Locations and Timber Availability in Selected U.S. States, USDA Forest Service, General Technical Report FPL-GTR-103, February, 1998

44 Hathaway, Fred, Norbord, Deposit, NY – personal communication August, 1998

45 Durbak, Irene, McKeever, Tim and Spelter, Henry, Review of Wood-Based Panel Sector in United States and Canada, USDA General Technical Report FPL-GTR-99, June 1997

46 1 cubic meter = 1,130 square feet of 3/8" board

**Figure 2**




Source: *Review of Wood-Based Panel Sector in US and Canada*, June 1997

Several factors have caused the large and swift increase in OSB capacity and production since the early 1980s. First, the sharp decline in the availability of (primarily) federal public timber since the early 1990s has caused industry to look carefully at plywood substitutes. Second, steadily increasing demand for structural board products has created additional demand (for plywood and OSB).

Structural panel (plywood and OSB) demand is expected to increase by 1 billion square feet (88.5 million cubic meters) in the 1998-99 period in the US market. This will outpace the extra capacity in the OSB industry by the end of 1999[47]. By the year 2000, current extra capacity in the structural panel industry will have been taken up by demand and new capacity will be needed. Approximately 50% of the North American structural panel market is being filled by OSB. This market share is increasing[48].

Is it possible that an OSB plant could be built in New Hampshire to fulfill increasing demand for structural panels in the year 2000? Many factors must be considered in forecasting such a possibility. These factors include:

- specific species availability,
- cost of raw material,

[47] APA – The Engineered Wood Association, Market Outlook 1998-1999, August 1997

[48] ibid

- cost of power,
- labor,
- potential for siting a plant.

Elmendorf Board Corp., the first operational OSB plant in the country began operation in 1980 at a site in Claremont, NH. The plant, which was later purchased by Texas-based Temple-Inland, shut down in 1988 due to a number of factors including: undersized design (not able to capitalize on economies of scale); cost of power and some species availability and cost problems (white pine high cost due, in part, to high moisture content). When operating, the plant used white pine and aspen as its main species. The first factor was easily the most important of those identified. Randall Johnson of Temple-Inland said that his firm is completing the sale of the idled plant machinery to a Canadian firm that plans to produce (in Canada) a specialty cedar OSB product, a solid cedar wood closet substitute[49].

In the early 1990s, as demand for OSB was catching up with supply in North America, Louisiana Pacific explored siting such a facility in northern New Hampshire. Since that time, Louisiana Pacific has built one plant in Wisconsin, two in Texas and one in North Carolina.

Species

OSB plants in Maine use primarily aspen as the raw material source. According to Steve Schaeller, Forest Products Specialist at the University of Maine, OSB manufacturers prefer lower density woods and those that have other desirable characteristics including ability to flake (in the OSB process roundwood is chopped into flakes horizontally), amount of resin in the wood and adhesion characteristics. The upper limit on density is a specific gravity of approximately .48. A list of key New Hampshire timber species and their specific gravity (a measure of density/hardness) is found in Table 1.

**Table 1 - Specific Gravity of Major Tree Species in New Hampshire**

| SPECIES | SPECIFIC GRAVITY |
|---|---|
| Aspen | .36 |
| Beech | .56 |
| White Birch | .48 |
| Yellow Birch | .55 |
| Red Maple | .49 |
| Sugar Maple | .63 |
| Red Oak | .56 |

| SPECIES | SPECIFIC GRAVITY |
|---|---|
| White Oak | .60 |
| Balsam Fir | .34 |
| Hemlock | .38 |
| White Pine | .34 |
| Red Spruce | .38 |
| White Spruce | .37 |

While the most desirable species mix used in OSB plants in Maine and Lakes States

[49] Johnson, Randall, personal communication, October 26, 1998

is aspen, a majority of the mills exist out of the aspen belts in those areas and use a variety of both softwood and hardwood species. Lee Clemons, manager at the Georgia Pacific OSB plant in Brookneal, Virginia said that they use Virginia Pine, Yellow Pine and Yellow Poplar in their species mix. Both this plant and another in Hope, West Virginia, keep their purchases of hard hardwoods to a minimum because their weight and hardness characteristics are not as desirable as those other species.

New Hampshire has an abundance of a number of species meeting the general characteristics needed to feed OSB raw material source. White Pine was a key species used in the now closed Claremont plant. While the characteristics of the species worked well, the high moisture content created problems on the cost side. When purchasing by weight, a high percentage of cost went into purchasing water in the wood. An alternative purchasing system might deal with the weight of water issue. Aspen is available in New Hampshire but if a plant were to be sited south of the White Mountains where low grade wood markets are most needed, aspen availability would be a concern. According to the forest inventory data from the USDA Forest Service, this species is more abundant north of the mountains and tends to be scattered.

Red Maple is now, based on the 1997 USDA Forest Inventory and Analysis for New Hampshire, the second most abundant tree species, by volume, growing in the state. Much of the standing timber in this species is low-quality. Red Maple is on the high end of the range of specific gravity of trees that can be readily manufactured into OSB. While OSB can be manufactured from this species, it would probably not make an acceptable product (board) if made *exclusively* from this single species due to the denser nature of the wood. Mixed with White Pine and Aspen, an acceptable product might be manufactured after testing board characteristics to determine optimum species mix. Hemlock, the fourth most abundant species, is also readily available. The Claremont plant used some Red Maple in its raw material mix back when it was operational. Like White Pine, Red Maple is readily available in the marketplace.

<u>Cost</u>

A new OSB plant is projected to consume 180,000 cords of wood per year (450,000 tons). At that significant volume, wood costs are a major component of overall plant costs (likely over 50% of plant operating costs – see next page). At $ 20 - $ 23 per ton in New Hampshire, wood costs are very favorable relative to other states where OSB plants are in operation[50]. Wood cost should not be problematic if a White Pine pricing structure can be instituted to take into account the high moisture content of the species. Newer wood handling systems used in the newer plants should allow the plant to purchase lower quality wood than was purchased at the Claremont plant (due to limitations in its wood handling and flaking equipment)[51]. The announcement in April of 1999 that the SAPPI pulp mill in Westbrook, Maine would be shutting down permanently will also reduce the demand for pulpwood grade roundwood in New Hampshire (the SAPPI mill purchased in excess of 500,000 tons annually primarily from Maine and New Hampshire), which will help keep

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[50] Arthur, Robert, Georgia Pacific, Mt. Hope, West Virginia, personal communication, September 24, 1998

[51] Gardner, Douglas, ibid

pulpwood prices stable or may even cause a short-term decline.

In 1996, an industry review of cost breakdown for OSB plants resulted in the following relative costs[52], on a percentage basis of total plant costs:

| | |
|---|---|
| Wood cost | 38% |
| Other costs | 18% |
| Glue & wax | 17% |
| Labor | 15% |
| Power & fuel | 12% |
| | 100% |

Cost of Power

Although not as significant a percentage of overall plant operating cost as compared to raw materials, cost of power is a significant factor. For the undersized Claremont facility that operated until 1988, annual electricity costs may have been as much as $ 1,000,000[53]. The annual cost for electricity for a modern plant is not readily available from current plant owners elsewhere in the US. As New Hampshire enters the deregulation of its electricity industry, it currently has the highest electricity costs in the nation, outside of Hawaii. Average power costs $ .1159 per kilowatt hour[54]. Deregulation promises to bring reductions in the 10-20% range, though large industrial users might see more significant reductions in cost. New Hampshire's nearest neighbor state likely to be a competitor for siting of a new OSB plant, Maine, has average power costs at $ .0946 per kilowatt hour[55]. While power will be a significant cost, at less than 12% of overall plant operation cost, it should not be an insurmountable factor, especially if deregulation becomes a reality.

Labor

Labor costs are approximately 15% of OSB plant operating costs as an industry standard. Even with low unemployment, the full-time benefits and generally higher wages an OSB plant would offer would make labor a lesser concern than when siting a sawmill plant, for instance. Labor availability and cost is not considered a debilitating factor in the potential siting of an OSB plant in New Hampshire although, as with other industries in today's tight labor market, challenges would have to be faced here as well.

Transportation

Major eastern markets for finished OSB product are much closer to New Hampshire

[52] Durbak, Irene, McKeever, Tim and Spelter, Henry, Review of Wood-Based Panel Sector in United States and Canada, USDA General Technical Report FPL-GTR-99, June 1997

[53] Bryce, Philip, former Elmendorf Board Corp. employee, personal communication, September 14, 1998

[54] U.S. Department of Energy, Energy Information Administration, State Electricity Profiles, April, 1999

[55] ibid

than they are to the Maine plants, the nearest competitors. This could provide a slight economic advantage to siting a plant in New Hampshire.

Given the many factors involved and cited above, once the current excess capacity of OSB manufacturing plants in North America is used up by increasing demand by the year 2000, and given the ability of the manufacturer to make an acceptable product from the White Pine, Aspen, Red Maple and possibly hemlock available, there is potential to site a plant in New Hampshire. Exploring the possibility of siting a plant at one of the wood energy plant locations (Tamworth currently has excess capacity and ample site room) for use of heat and power, could be an added incentive.

## IV. 8 *Firewood*

Residential firewood use in New Hampshire, which utilizes largely low-quality hardwoods from New Hampshire forests, has declined steadily over the past 15 years. New Hampshire is now consuming less than half of the firewood that it did in 1983[56]. In the 1983-84 heating season, 500,000 cords were consumed for this purpose while in 1996-97, 200,000 cords were used.

Whereas 46% of households burned wood as a primary or secondary heating source in 1983-84, that number declined to 21.7% in the 1996-97 heating season. (Table 2)

**Table 2**

| Year | % Primary Wood Users | % Secondary Wood Users | % Wood Users |
|---|---|---|---|
| 83-84 | 30 | 16 | 46 |
| 84-85 | 34.3 | 15.5 | 49.8 |
| 85-86 | 24.8 | 15.5 | 40.3 |
| 86-87 | 28.5 | 16 | 44.5 |
| 87-88 | 17.3 | 16 | 33.3 |
| 88-89 | 11.7 | 12 | 23.7 |
| 89-90 | 12.8 | 20 | 32.8 |
| 90-91 | 11.7 | 23.3 | 35 |
| 91-92 | 12 | 15.5 | 27.5 |
| 92-93 | 13.3 | 13.5 | 26.8 |
| 93-94 | 13.7 | 19 | 32.7 |
| 94-95 | 9.5 | 14.2 | 23.7 |
| 95-96 | 9.5 | 15.7 | 25.2 |
| 96-97 | 8.5 | 13.2 | 21.7 |

Wood use in this sector is not likely to increase in any significant way in the near future if oil and natural gas prices continue to be priced at or near current levels. Most of these conventional petroleum-based sources of heat are cheaper than firewood when firewood is purchased in the marketplace (versus 'cut your own'). With the general population slowly aging, it is unlikely that a greater percentage of wood users will benefit from the savings realized by utilizing 'cut your own' firewood. Indeed, the most recent residential wood heat survey showed that the 'amount of work' was cited as a major reason

[56] 1996-97 New Hampshire Residential Wood Heat Survey, State of New Hampshire, GOECS, September 1997

why non-wood burning households were unlikely to use wood in the future[57].

Household firewood use levels are directly dependent on the price of more conventional fuels. It is very unlikely that firewood use will increase significantly unless oil and natural gas prices increase dramatically. There is very little evidence that conventional fuels will spike in price anywhere near that of the early 1980's when firewood use skyrocketed in response.

## IV.9 *Animal bedding*

Use of wood residues from sawmills, chiefly sawdust, as bedding for farm animals has been traditional in New Hampshire and elsewhere in the northeast for much of this and the previous centuries. This use is often seasonal with more use of sawdust in the winter when farm animals tend to be in barns more. Recent experiments with shredded newspaper and other substitutes have not worked out well and demand for sawdust and wood shavings for this purpose is increasing[58], mostly from horse use (shavings). As a sector in the agricultural industry, raising horses is expanding in New Hampshire.

The potential for using green chip based materials for animal bedding is poor given the needs for a finer product (such as sawdust) at low cost. The animal bedding market has little to offer in seeking out low-grade wood alternatives to the wood energy plants.

## IV.10 *Mulch for landscaping*

Several northeastern companies in the business of providing organic mulch for landscaping purposes have recently used green wood chips to supplement their supplies of bark and other more desirable mulching products. Wood Recycling Inc. of Wobum, Massachusetts and Jolly Gardener, Inc. of Maine are the two leaders in this industry. Wood chips are not entirely substitutable for more desirable mulching products like bark. Color and fermentation/degradation problems top the list. Green chips are mixed with dry chips from pallet grindings and sawmill chips to increase volumes but only as a last resort. Dye products are used to darken the bright colored wood chips (as compared to bark mulch – the most desirable product) and the dyes run and fade easily in green chips.

Currently it is estimated that approximately 25,000 tons (1000 truck loads) of wood chips are used for this purpose in the whole of the northeast[59]. Of this, no more than 80% or 20,000 tons, is from green or whole tree chips. Most of these chips are from southern New England land clearing sources and have no ready markets (the northern New England markets are too distant) so the chips are "dumped" into the landscaping market at reduced prices. The potential for expansion in this market is very low.

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[57] ibid

[58] NH Dept. of Agriculture

[59] Cook, Doug, Ingerson, Mitch, personal conversations, October, 1998

## IV.11 *Densified logs*

Artificial or "densified" logs are made from wood chips, saw dust and shavings. The current raw material is recycled construction and demolition waste wood with negative cost to the manufacturer. Prospects for using green wood chips or other low-quality product from the forest in this product are poor in competition with recycled wood which is still in good supply in urban and nearby areas. The product also competes directly with firewood and therefore there seems little prospect of a large market developing.

## IV.12 *Pulp and paper*

Prior to the introduction of the wood energy plants in New Hampshire in the mid-1980s (and the advent of the now-closed OSB plant in Claremont, NH), there were only two large markets for low-quality wood in the state: firewood and pulpwood for the pulp and paper industry. The firewood situation has been discussed above.

Pulp and paper markets have been available for low quality wood fiber for over 100 years in New Hampshire. These markets, though not all located within the confines of the state boundary, are still substantial and very viable. They are located in New Hampshire, Maine and New York (with the New Hampshire and Maine markets being the most substantial). According to drain data (Timber Product Output or TPO) developed by the U.S. Forest Service as part of the 1997 Forest Inventory and Analysis, pulpwood markets receiving wood from New Hampshire sources totaled 1,110,360 cords (2,775,900 tons) in 1996. The New Hampshire based pulpwood markets, Crown Vantage in Berlin and Groveton Paperboard in Groveton, represent 50-60% of those markets.

The other markets represented in this industry are located in Westbrook, Maine (SAPPI – soon to be closed), Rumford, Maine (Mead Corp.) and Jay, Maine (International Paper). Other lesser markets include Finch Pruyn & Co. in Glens Falls, New York, International Paper in Ticonderoga, New York and other minor markets in Maine and Canada.

Obviously, the size of these low-quality wood markets dwarf that of the wood energy industry in New Hampshire. And until the last 10 years, most of the pulp wood from New Hampshire forest lands came from the northern part of the state. In recent years, many of the pulpwood markets outside of New Hampshire have developed remote purchasing yards. Even the Crown Vantage facility has located a yard in southern NH in recent years.

The pulp and paper industry produces a commodity product (pulp and paper) that is sold globally. The economic health and future prospects for this industry in the northeast is more dependent on forces of a global nature than on local economies. Japan has a large paper making industry and countries such as Chile, Indonesia, Thailand, Taiwan, and South Korea are rapidly developing world-class paper making industries. Furthermore, their fiber (wood) costs are likely to be lower than fiber costs in the developed nations, due to lower labor costs as well as lower growing costs. These lower growing costs are a result of an explosion of industrial plantations which grow fiber at up to ten times the rate we experience in New England. Plantations are expanding in South America and in Australia and New Zealand, among other areas. The result of this new, low cost paper making capacity could mean downsizing in the paper industry in North America. The downsizing could be particularly severe if an economic downturn slows demand globally for paper products, because new low cost capacity coming on line in the next few years could push the paper industry here in North America into the higher end of the cost curve.

Despite this phenomenon, it is very unlikely that the status of pulp and paper facilities in New Hampshire, Maine and New York will change soon. Even the most economically challenged plant, the Crown Vantage operation in Berlin, NH, is likely to continue to operate for some years to come. New pulp and paper mills are not being constructed in the United States and, given the very difficult siting processes and public influence on industrial sitings of this kind, generally, due to environmental concerns, it is very unlikely that any new facilities will be built in this country in the next 40 years. Good evidence of the value or these existing pulp mill locations can be shown by the fact that the Crown Vantage facilities will soon be sold to American Tissue Corp. The purchase price of $ 45 million is generally considered a low price given the extensive pulp and paper making facilities in Berlin and Gorham and recent capital improvements costing nearly as much.

IV.13 *Co-firing at coal plants*

Supplementing different fuels in boilers designed to burn exclusively coal is referred to as co-firing. This is different than utilizing different fuels in a "multiple fuel boiler" designed to burn many fuels, such as oil, gas, coal, biomass, and paper sludge separately. Co-firing has seen increasing interest among some utilities. The application of co-firing appears to be very site specific, depending on both the boiler specifications **and** the source and cost of the fuel being co-fired[60]. Co-firing with biomass has been successfully applied at several coal-fired plants around the country.

There appears to be some potential for co-firing wood chips with coal in New Hampshire. There are two coal fired utility power plants in New Hampshire, the Merrimack Station in Bow (440 MW in two cyclone units) and the Schiller Station in Portsmouth (150 MW in three pulverized coal units), both owned and operated by PSNH. The Schiller Station is not a particularly good candidate for co-firing:

1) It is a pulverized coal unit, which requires fuel to be crushed to almost a powder type consistency. Although co-firing at pulverized coal units has been done successfully, it is typically done with furniture waste or other dry wood waste. Again, this study is focused on alternatives for utilizing green whole tree chips, which would be much more difficult to prepare for a pulverized unit;

2) Pulverized coal plants are typically much more difficult to co-fire than cyclone units, because they are more sensitive to variations in their fuel quality[61].

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[60] Tillman, David, Foster Wheeler, personal communication, November, 1998

[61] Goldberg, Philip, Dept. of Energy, personal communication, November, 1998

3) A large natural gas pipeline has recently been constructed within close proximity to Schiller Station and there have been reports that PSNH is planning to burn natural gas there.

The Merrimack Station is a better candidate for co-firing with whole tree chips. It is centrally located in the State, near the junction of two major interstates. It has cyclone boilers, which have been successfully co-fired with green wood at several locations around the country[62]. There is also a larger area adjacent to the plant to draw wood from. However, there are several obstacles that may make co-firing at Merrimack Station difficult.

During the winter of 1994-95, Merrimack Station experimented with co-firing wood chips, without much success. At first, the staff at Merrimack Station tried firing 7/8" chips as produced. The fuel in cyclone boilers is designed to burn on the cyclone wall and the coal is sized to pea size in order to accomplish that. The wood chips were exiting the cyclone and entering the furnace itself before being completely burned. Thus, the plant experienced problems with wood chips not burning completely[63]. The staff at the Merrimack Station believed the wood chips were being blown through the cyclone because they were too light for their shape and size[64]. When they tried reducing the size of the wood chips to ¼" minus, they experienced the same problem of incomplete burning of the wood chips. These trial burns at Merrimack Station were done in the face of political controversy surrounding the proposed closure of some of the wood plants.

There has been considerable work done on co-firing wood with coal in cyclone boilers since 1994 elsewhere in the country. One of the conclusions of that work is that the feasibility of co-firing wood with coal in cyclone boilers is very site specific, depending on various design features which vary from plant to plant[65]. Merrimack Station is a similar size to TVA's Allen Fossil Plant in Memphis Tennessee which has successfully co-fired wood[66]. However, design features such as the amount of excess air, fuel residence time in the cyclone, fuel residence time in the furnace, excess capacity of both the forced draft and the induced draft fans, fuel feeder capacity and fuel feeder design need to be evaluated for their acceptability for co-firing. Although it is possible that Merrimack Station could be modified to co-fire wood with coal despite the poor results during its trial in 1994, it is not necessarily feasible[67]. Technical analysis beyond the scope of this work is necessary to determine the viability of co-firing wood. Notwithstanding, a co-firing rate in the range of 5-7% on a BTU input basis, is the likely co-firing rate which is viable at Merrimack Station. This equates to a wood consumption rate of approximately 270,000 tons per year.

The economic viability of co-firing wood with coal is also site specific. Where a disposal problem exists for wood waste such as furniture waste and sawmill residue, co-firing is often economically viable. However, the focus of this analysis is to assess the viability of

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[62] Tillman and Goldberg, personal communication

[63] Keyes, Harold, personal communication October, 1998

[64] ibid

[65] Tillman, David, personal communication, December 8, 1998

[66] ibid

[67] Tillman

co-firing whole tree chips. In central New Hampshire, we estimate that, at a 7% co-firing rate on a BTU basis, the 270,000 tons of whole tree chips could be purchased for an average price of $16.00/ton, or about $1.80/MM BTU. This is roughly equivalent to the current cost of coal purchased at Merrimack Station ($1.85/MM BTU)[68]. On a pure energy cost basis, there is thus little reason for Merrimack Station to co-fire wood with coal because there are no savings to be realized. Furthermore, whole tree chips delivered directly from the woods must be reduced in size to about ¼" in order to be potentially burned in a cyclone burner[69] The capital and operating cost of this particle reduction is about $5.00/ton or about $.50/MM BTU. Thus the true cost of purchasing and preparing the fuel is likely closer to $2.30/MM BTU.

From a purely economic standpoint, there is little reason for Merrimack Station to co-fire whole tree chips although a US Department of Treasury proposal to allow for a 1.0 cent per kwh tax credit for co-firing would help. There must be other external factors that would make co-firing a viable alternative for PSNH. One potential external factor is air emissions conformance, particularly as it relates to $SO_2$ and particulates.

According to personnel at the NH Department of Environmental Services Air Resources Division[70], PSNH is well on its way to dealing with NOx emission reductions required by 2003 at Merrimack Station. After a retrofit of Unit 1 at Merrimack recently announced by PSNH, the plant will be ahead of the 2003 target. For $SO_2$ emission conformance, PSNH is in compliance through purchase of emission credits from other companies who are ahead in their $SO_2$ emission reduction conformance. Merrimack Station could benefit from use of wood to replace the need for credit purchase. The new EPA particulate regulations are not formulated yet under the new 2.5 standard but Merrimack station could likely benefit from co-firing with wood in that regard as well although the targets and requirements are not yet set.

The Phase III NOx reductions that begin in 2003 will require additional reductions over current levels in the 1999-2002 Phase II and, according to Joseph Fontaine at DES Air Resources, a working group studying options is discussing the role that renewables such as wood, along with energy efficiency, might play in the Phase III period.

In addition, as evidenced by their 1994-95 trial burn with wood chips at Merrimack Station, PSNH has an incentive to co-fire wood in order to create an alternative market for low grade wood chips. About 700,000 tons of wood chips a year currently are purchased from New Hampshire suppliers and burned in several wood-fired power plants in the State. These plants are under contract to sell their power to PSNH at electric rates above the market price for power. If PSNH could create a market for at least some of these wood chips by co-firing at Merrimack Station, the company would relieve some of the political pressure to continue purchasing higher cost power from the wood fired power plants that are under contract.

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[68] Public Utilities Commission

[69] Tillman, David

[70] Fontaine, Joseph, NH DES, personal communication, December, 1998

# V. Likely low grade wood market expansions and new markets in the 1999-2003 period

The dilemma posed early in this paper – what can New Hampshire do to secure alternative low-grade wood markets should the wood energy markets be reduced or eliminated in the near future and to respond to the ice storm damage – has led us to investigate a wide range of opportunities that exist or may exist. The added burden to the market place caused by the January 1998 ice storm that affected more than 700,000 acres in New Hampshire alone and a much greater acreage in Maine, Vermont and New York, is significant.

To further make clear the focus of this study, we have investigated opportunities that:

- Can be developed commercially within the next 3-5 years (or are current markets expandable during that period);
- Are markets or potential markets that draw on "green" wood from the forests of New Hampshire, not residues from primary manufacturers;
- Offer substantial market opportunities in the face of a threatened loss of market for 700,000 tons per year of purchased wood chips from New Hampshire sources.

**Based on our investigations and research, we believe that no sure substitutes exist for replacement of portions or all of the wood energy markets during the next 1999-2003 period. No shining star candidates emerged from our efforts. Despite this, and with recommendations for public policy implications articulated in the following sections of this report, we believe the greatest potential exists for market expansion meeting the three step test described immediately above to include:**

- **Green power marketing of the existing wood energy plants**
- **Siting of an Oriented Strand Board plant**
- **Co-firing of Public Service Company of New Hampshire's Bow coal plant with wood**
- **Wood chip exporting**
- **Use of wood sources for production of bio-fuels/bio-chemicals**

# VI. Costs of alternative low-grade wood markets and identification of barriers to creation and/or expansion of markets

## VI.1 Costs of alternatives

**Green power** marketing of the existing wood energy plant outputs after buydown or end of rate-orders will require no capital cost infusion from the plant owners or other entities. The plants would simply operate as they have but under a pricing structure that was outside the current rate-order pricing and within a deregulated market.

The cost of siting an **Oriented Strand Board** plant in New Hampshire would approach $ 50 million based on the most recent scale plants built in North America. This size plant would provide a market for approximately 180,000 cords of wood per year (450,000 tons). Obviously, this is a very large market and, should one be created, could go a long ways towards addressing a reduced or eliminated wood chip market currently provided through the energy plants.

**Co-firing** the Bow coal power plant with wood at 5-7% of power output capacity would result in a market of approximately 270,000 tons of whole tree chips per year. In order to handle that wood, re-manufacturing of the size of the chips would be required at the Bow facility or at some other location prior to utilizing the raw material. It is estimated that capital costs associated with that re-manufacturing would cost $5/ton using a secondary grinder facility. Other capital costs are impossible to estimate until a full engineering analysis is completed for the plant. While machinery for making smaller sized chips off-site could be used as a substitute for re-manufacturing, no such machinery is currently commercially available for this purpose.

**Wood chip export** of paper grade wood chips to western Europe (the likeliest near-term market) would require capital expenditures to upgrade the Port of Portsmouth facility to handle wood chips. It is estimated that these costs should likely be less than $ 1,000,000, but further investigations are needed. Currently, the infrastructure within the wood chipping industry exists to handle any export markets that might be gained, so no new costs are contemplated for the industry in that regard.

Use of wood sources for **production of biofuels and biochemicals** would take the form of an ethanol or Levulinic Acid plant. Cost estimates for siting these plants range from $ 100 million to $ 250 million. Since neither of these kinds of facilities have been built, it is difficult to estimate capital costs.

## VI.2 Barriers to market creation

For the four potential markets described in the previous section, significant barriers exist that, unless removed, will prevent the actual creation or expansion of these markets.

**Green power marketing of the existing wood energy plants** – At present, in a deregulated market, the wood energy plants would not be able to survive at market rates being paid for power at the wholesale level ($.03-.035/Kwh). Further, without incentives or government mandates that would require renewable energy sources be a part (or percentage)of the deregulated market, consumers may not even have the choice to purchase power from wood-based sources (the plants would likely shut down if placed in a completely open market at this time).

Market data cited elsewhere in this report suggests that consumer demand for "green" power alone would not be sufficient to assure market viability of the wood plants in a deregulated market and with the current rate-orders expired. Nothing would require that electricity providers have green power sources available for consumers to choose from. This is a significant barrier to marketing power from the wood plants as "green" power.

**Siting an Oriented Strand Board plant** – A number of significant barriers exist to suggest that siting an Oriented Strand Board plant in New Hampshire would be a challenge. First, the current production capacity of the existing OSB plants in North America is adequately meeting the present demand although a variety of factors stretched that capacity in late 1998, causing a 20% price increase in the OSB product. If trends continue as predicted, the demand should increase beyond capacity sometime in the next 2 years. A downturn in the economy, which some are predicting in the next 18 months, could have serious consequences in that regard.

Another major barrier to siting an OSB plant in NH is the wood species mix available to make the product. While some species are available in adequate quantities, some are less desirable than others when contemplating making OSB. The first order species would be aspen, which, marginally, could be had in adequate quantities but would suggest a northern location if that species was sought alone. This would put the market a distance from the southern part of the state where the lack of low-grade markets is greater and more likely to be in conflict with existing markets. If the desired species mix included white pine, red maple and hemlock in addition to aspen, other siting locations would be possible.

Other barriers would include cost of power and labor though neither are considered barriers of the order described above.

**Co-firing of Public Service Company of New Hampshire's Bow coal plant with wood** – At the time of the writing of this report, it has not been possible to determine if the co-firing of the Bow coal plant with a small portion of wood is technically possible. A test firing in 1995 suggested major problems in this regard but no further investigations were made at that time. Before Public Service Company could decide if it wanted to use wood at the Bow plant to reduce air emissions or other reasons, a thorough engineering analysis would have to be undertaken.

Another potential barrier is the motivation or lack of motivation on the part of PSNH to make a partial conversion at the Bow plant. The only potential motivations for such a change on the horizon are new air emission standard changes in 2003 for NOx, $SO_2$ reduction needs, the unsure future particulates regulations under the new EPA 2.5 standard and the political pressure caused in the wood energy plant buy-down scenarios. Since the legislature has agreed, at least to a limited extent, that maintenance of the low-grade wood markets represented in the wood energy plants is a public policy of the State, moves to change that policy would likely come partnered with the recognition that these low-grade markets are very important.

A final barrier at the Bow plant would be the capital cost associated with burning wood at the plant, especially in the face of deregulation and the potential sale of generating assets by PSNH. At the very least this would involve an on or off-site facility to re-manufacture traditionally produced whole tree chips into smaller sized, more uniform materials (or finding new machinery to produce smaller sized chips in the woods). Other possible capital costs might involve retro-fitting various support equipment such as fuel feeders, various fans, and/or other equipment which supports combustion in the cyclone. An estimate of the capital required to potentially co-fire wood at Merrimack Station is purely speculative due to the individualistic nature of converting a particular plant.

**Wood chip export -** Currently, two barriers have been identified that are preventing access to western European pulp and paper markets for wood chip export from the Port of Portsmouth. The price at which paper-grade chips could be provided to export markets has been the main stumbling block of several recent attempts at reaching these markets. In 1999, the gap appears to be nearly closed so it is expected that a deal to ship wood chips will be consummated during the 3-5 year window of this analysis.

The more significant barrier appears to be a new one – fumigation requirements by the European Union to prevent importation of nematodes. It is estimate that fumigation of wood chips could cost as much as $ 8/green ton, if the technology could be made available at all. This increase in cost would make wood chip export uneconomical from New Hampshire.

Despite some significant capital costs associated with upgrading the Port of Portsmouth facility to handle wood chips, we do not believe this to be a barrier because of the eagerness of the Port officials to upgrade the facility for wood chip export.

**Use of wood sources for production of biofuels and biochemicals** – Of the potential markets identified, the chemical production market is the most tenuous given the lack of commercial operations of these kinds. Barriers to this kind of new market include the technical ones associated with bringing test-case technology into commercial operation along with the enormous financing needed to bring such untested operations on line. According to Pen Cor principals, a ready market is available for Levulinic Acid but this is not necessarily the case for ethanol though the use is widespread.

# VII. Timber resource analysis, availability and sustainability

In order to determine the sustainability of the forests of New Hampshire, an analysis of the level of timber harvesting relative to the standing volume of timber and growth is needed. For this study, this analysis is constrained by possible future scenarios with changes in the wood energy industry and other forest products markets or potential markets.

We have reviewed the situation and have undertaken a modeling analysis with the assistance of Resource Systems Group under the following scenarios:

- current market structure;
- under a re-structured market where the pending buy-downs of the six wood energy plants are completed; and
- under a re-structured market where the complete shut-down of the six wood energy plants occurs.

A detailed review of methods and output data can be found in Appendix C.

Major Findings – Harvests Sustainable

***Under all future scenarios identified, growth exceeds drain by at least 2.4 times and at most, by 3.4 times.*** This suggests ample supply of forest stocking today (with six plants still operating) and, obviously, in the future should the plant buy-downs or buy-outs occur.

Analyzing the data in Appendix G, which breaks down the growth and drain model projections species by species, a review of two key species considered more heavily harvested shows similar findings. In the worse case year, 1997 (before projections for buy-downs are begun) at the 60% availability level, White Pine growth is at 27.13 million cubic feet statewide while drain is 16.04 million cubic feet – a growth to drain ratio of 1.7:1. For Red Oak the growth is at 14.98 million cubic feet to a 7.21 million cubic feet drain -- a growth to drain ratio of 2.1:1.

What this analysis does not show is how these species, or others, would fare at a regional level. Should the siting of new wood using plants be considered, local and regional supply analysis for timber should be accomplished to assure sustainable harvest levels.

How Sustainable Forestry can be encouraged in expanding wood market situations

According to the timber sustainability analysis conducted for this project, ample supplies of wood fiber exist from New Hampshire sources to supply any of the four likeliest markets, even should the wood energy markets that exist today not be reduced during the 3-

5 year study horizon. Current stocking and net growth in New Hampshire's forests from the 1997 released US Forest Service Forest Inventory and Analysis (FIA) data show ample room for expansion, especially in the low quality end.

Total growing stock from hardwood and softwoods from the 1997 FIA showed 9,020.8 million cubic feet of wood. Total removals from the 1996 Timber Product Output dataset from the US Forest Service was 87.2 million cubic feet for the year. Using gross figures only, this removal rate is approximately 0.97 % of total growing stock. At a conservative average *net* growth figure of 2.5% for all softwoods and hardwoods[71], the 1996 harvest levels were only 39% of growth. If we discount the total growing stock by 30% to account for lack of availability due to regulatory, physical and other reasons cited earlier, the removal rate is 1.4% of total growing stock and 56% of *net* growth. If we were to double our overall harvesting levels from the 1996 levels to 174 million cubic feet annually, and keeping the availability at the 70% level, removals would be approximately 2.7 %, or about equal to net growth. Review of the modeling work earlier in this paper confirms this in projections to 2015.

From a timber only perspective then, we have little to worry about in terms of over-harvesting the fiber represented on the trees in the forests of New Hampshire. If we accomplished a species by species and product by product analysis and did so on a localized or regional level within the state, we might find areas of concern such as with white pine sawtimber or oak sawtimber. From a pure timber volume perspective, however, we are harvesting at infinitely conservative and sustainable rates. But not harvesting close to growth levels results in potential negative consequences as our forests mature – insect and disease susceptibility being one.

Sustainability means more than simple determination of timber volume harvest levels relative to growth and availability, however. Sustainable forest management takes into account many more of the natural resource values than simply the timber. Concerns for biodiversity conservation, water quality and quantity, wildlife and its associated habitat, soil retention, aesthetics, natural communities and other considerations are all part of the sustainability question.

It is recommended that all expanded or new markets promoted as a result of this study take steps to assure overall sustainable forest practices are carried on timber harvesting taking place to fulfill market needs. Several alternatives should be considered by those creating or expanding wood markets to assure sustainable practices. In some cases, use of more than one of the alternatives is recommended.

a) **Sustainable Forestry Initiative**SM (SFI) is a program of the forest products industry through the industry trade group the American Forest & Paper Association. Members and licensees must abide by a series of sustainable forestry principles and guidelines while annually reporting their activities. SFI is a voluntary program but those wanting continued membership or licensee privileges must comply with the program requirements. Recently,

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71 Newfound Economic Development Region Timber Inventory and Analysis, Newfound Economic Development Corp., July 1996 and Leak, William, personal conversation, May, 1996

SFI developed its program into an industry standard based on the International Standards Organization format (ISO). Through a new Voluntary Verification program, member companies or licensees can choose to have third party certification of their practices under the SFI standard.

b) The **Forest Stewardship Council** is an international private sector body that develops standards for sustainable forestry and certifies certifiers (companies and non-profits) who measure practices of those seeking certification against the standards. Those landowners and mills certified are granted use of a green certification label for forest products resulting from certified company operations. Marketplace recognition of this standard, not necessarily price advantage, is the centerpiece of the program.

c) It is recommended that all those who practice forestry in New Hampshire utilize the recommended sustainability practices contained in the publication **"Good Forestry in the Granite State"**[72]. A multi-year stakeholder process resulted in this handbook that contains an nearly exhaustive list of on-the-ground practices that can be used by those who are interested in undertaking forest management activities that consider and seek to conserve the full range of natural resources present in our forests.

d) A final recommendation is for markets of wood products to consider utilizing **price premiums for wood harvested using sustainable practices**. Several alternatives exist to encourage good practices using market price premiums:

- Use of a licensed forester as part of management activities (Pine Tree Power provides such incentives currently under its TREE program);
- Recognizing FSC certified forestlands;
- Recognizing use of NH Professional Logging Program certified loggers;
- Recognition of SFI companies.

[72] Available through the Society for the Protection of New Hampshire Forests, 54 Portsmouth Street, Concord, NH 03301, 603-224-9945

# VIII. Recommended policies to encourage retention, creation and/or expansion of low-grade wood resource markets in New Hampshire

Economic development, where new businesses are created or businesses are expanded, often results from an entrepreneur taking a significant risk. In those situations, hopefully the market, resources, labor and other input factors come together to make a profitable and sustaining business venture. Public policy designed to support economic development will often be supportive of the entrepreneur who has decided to take a risk. In other situations, government intervention, at least at time of start-up, is essential to desirable economic development outcomes. The development of the wood energy industry in New Hampshire is a case in point. The Public Utility Regulatory Policy Act (PURPA) and the state Limited Electrical Energy Producer Act (LEEPA) incentives for renewable energy sources required the purchase of the power and long-term rate orders allowed for financing to occur. Government intervention with a directed policy to encourage renewables resulted in the birth of the industry.

## VIII.1 **Green power marketing of the existing wood energy plants**

As described in the barriers section above, in a deregulated market, the wood energy plants would not be able to survive at current (or expected) market rates. We believe that the best way to alleviate the problems associated with reducing or eliminating the low-grade wood markets represented by the wood energy plants is to make every effort to keep these markets open. Building new facilities for the other potential markets we describe is very risky and with capital costs nearly covered for the existing plants, finding some way to allow them to operate in a deregulated market should be a high priority for the State of New Hampshire.

Given those arguments, we believe explicit public policy is essential if the wood energy markets are to have opportunities for survival as "green" power in a deregulated market. Specifically, we recommend that the State set a policy that articulates the desire to encourage renewables as part of the power source mix and that it explore several approaches to doing so:

⇒ Establish a minimum "renewable portfolio standard" (RPS) where an electricity provider must offer a certain minimum percentage of its power for sale from a renewable source. This will require providers to have renewables as part of their mix although it would not require consumers to purchase such power. Consumers would choose to purchase from the wood energy or other renewables sources at a premium;

⇒ Establish a surcharge for all customers, the proceeds from which go into a fund for the commercial establishment/maintenance of renewable power sources.

⇒ Establishing a rebate for customers who purchase their power from green power providers. This has been implemented in California.

Additionally, if encouraging renewables is deemed sound public policy for the state, we must take into account that over 30% of the ratebase is not within PSNH territory and recognize that all of the ratepayers play a role in encouraging renewables, not simply those within the current PSNH area.

## VIII.2 **Siting an Oriented Strand Board plant**

Siting an Oriented Strand Board plant will result from a careful alignment of market demand, industry capacity (or lack-thereof as demand increases in the next few years), timber species availability and aggressive state economic development personnel activities. There is serious potential for this to occur in New Hampshire. Given the data available and projected future demand, it appears that the time is ripe ***today*** to begin aggressively pursuing a plant – to meet increased demand 2 years out, plant development needs to occur today.

In the case of an OSB plant siting, no direct action by the legislature or governor is suggested. Instead, it is recommended that personnel in the Department of Resources and Economic Development (DRED), Economic Development Division, become familiar with the OSB market situation in North America, monitor it for signs of expansion, and begin making contacts with likely plant builders today, particularly the owners of the northeastern facilities and Louisiana Pacific. DRED personnel should know when the industry is looking to expand capacity and be aggressive about encouraging that expansion to occur in New Hampshire, providing the link with likely communities, those in the wood supply field and labor contacts.

Exploring the co-locating of an OSB plant at one of the wood energy plant sites also appears to have promise. In particular, the Tamworth plant has excess capacity that could provide a ready source of heat and power and the site has ample room for expansion. Other plant sites are also worth exploring.

## VIII.3 **Co-firing of the Bow, NH coal plant with wood**

The biggest barrier to co-firing the Merrimack Station coal plant with wood is the lack of proper technical understanding about the potential for doing so. It is recommended that an outside expert who has experience in successfully co-firing with wood at a cyclone boiler type plant, be hired to complete a fuel analysis of the situation. The Governor's Office of Energy and Community Services (GOECS) along with the DRED should take the lead in this endeavor. The plant owners need to be convinced of the value of undertaking such an endeavor. Additionally, NH Dept. of Environmental Services Air Resources representatives need to explore the air emission reduction benefits associated with co-firing with wood at Merrimack.

VIII.4 **Wood chip export**

The major barrier preventing the likelihood of wood chip export for paper making to western Europe from New Hampshire is the European Union nematode fumigation requirements for shipping wood chips. State of New Hampshire trade officials should pursue dialogue with the European Union on this subject. The source of the requirement began as a result of wood chip export concerns from the southeastern U.S.

From conversations with Port of Portsmouth officials in 1999, it appears that the Port is ready to make capital improvements at the site in order to handle wood chip exports[73]. This is a very necessary government action if wood chip exports from the Port are to become a reality.

VIII.5 **Use of wood sources for production of biofuels and biochemicals**

The technical and financial uncertainty of siting an ethanol or Levulinic Acid production facility using wood as the main feedstock requires careful assessment by the developers. It is recommended that DRED economic development officials develop and maintain good relationships with potential developers of these facilities in order to facilitate a New Hampshire siting should plans firm to begin construction. Exploration of state backed or assisted financing for such an endeavor should also be considered depending on the needs of the developer.

An additional action by the DRED office along with the GOECS is to develop a relationship with the principals who have purchased the former Bristol Energy plant in Alexandria, the Indeck Corp. This site has great potential for either of these operations and additionally may serve a co-locating industry such as discussed earlier, if power can also be sold in a "green" deregulated market.

Diligence on the part of the state's economic development officials is the likeliest ingredient for success here, once the other factors appear favorable.

Of the potential markets identified, the chemical production market is the most tenuous given the lack of commercial operations of these kinds. Barriers to this kind of new market include the technical ones associated with bringing test-case technology into commercial operation along with the enormous financing needed to bring such untested operations on line. According to Pen Cor principals, a ready market is available for Levulinic Acid but this is not necessarily the case for ethanol though the use is widespread.

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[73] Foss, Stephen, Port of Portsmouth, personal conversations 4/7/99

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# Appendices

# Appendix A

**Summary of literature search on alternative markets for harvested wood chips and low value hardwoods.**

In addition to those markets listed in the project outline the following are worth noting.

## WOOD/PLASTIC COMPOSITE PRODUCTS:

Wood chips are mixed as a filler and strengthening agent with recycled or virgin plastics. The main products are for decking and outdoor furniture but a wide range of products can be made. No New England companies have been identified at present. Recycled plastic products generally are having a hard time finding large enough markets. Production at present is small. Timbrex brand, a division of Mobil Chemical Company, is the leading producer. The prospects for this product seem only moderate and it is unlikely to become a large market in the near future.

References: SERBEP, 1994, A source book on wood waste recovery and recycling in the Southeast, TVA Muscle Shoals AL., Section IV, Current and potential end uses for recycled wood.

## WOOD/ ASPHALT AGGREGATE.

Wood chips can be mixed with asphalt to make a soft resilient aggregate suitable for use in play grounds or roads. Advantages claimed for it are that it is softer than regular aggregate but no information is available on how well the product wears over time. No New England manufacturers have been identified at present. The prospects for this product seem only moderate and it is unlikely to become a large market in the near future as the market is very specialized. If this market develops it would seem to be a first choice for waste treated wood chips rather than natural harvested wood chips. The exception may be when used for children's playgrounds. A rival product uses scrap tires which have negative disposal costs.

References: SERBEP, 1994, A source book on wood waste recovery and recycling in the Southeast, TVA Muscle Shoals AL., Section IV, Current and potential end uses for recycled wood.

## WOOD/CONCRETE BUILDING PANELS:

Wood chips, or other biomass wastes, are mixed with concrete to make a tongue and groove panel used for building construction. Advantages claimed are that the product is lighter and has better insulation value. It may appeal to the DIY market and construction costs are below conventional methods. No New England manufacturers have been identified at present. This product is sometimes called "Chunkrete". Acotec is one of the leading producers. Prospects for this product appear to be only moderate. Residential concrete construction is not favored in the Northeastern states and the conservatism of the building trades and customers preferences make it unlikely that this product will become important in the near future. Other uses for wood/concrete such road barriers, flooring and decking , where light weight is important, may have greater potential.

References: High Fiber House, Popular Science Jul 1 1990, v237 (1) p 80.

## MEDIUM DENSITY FIBERBOARD (MDF):

MDF is a wood board made from fine ground wood (92%) and urea based glues (8%). This product is available on the market at present. It provides an excellent base for veneer or it can be painted to look like wood. Problems are formaldehyde release, as with other glue fiber products. Use of MDF is growing but currently the plants are in the South and West. Prospects in New England are only moderate as softwood is preferred and sawmill waste is often used.

Reference: Materials: Why MDF now gets some respect, This Old House, June 1998, p53 – 56

## LAMINATED AND ORIENTED STRAND DIMENSIONED LUMBER:

These products are made from small pieces of wood glued into planks 2x4's laminated trusses etc. These products are not made from chips but use specially cut pieces with the grain orientation along the main axis of the lumber. The product uses smaller dimension logs and wood that might otherwise be unmarketable as dimension lumber. Specialized production facilities are needed. Hardwood chips can be used but softwood or light hardwoods (poplar) are preferred. The main manufacturer is T.J. International. (see http://www.tjco.com) with approximately 60% of the market for these products. It has 15 facilities in the US and Canada but it is not currently active in New England. The prospects in New England are moderate in the near-term but this is likely to be a strong growth area in the long-term. This industry has a high value added component.

References: K.E. Skog et al. 1995, Wood products technology trends: changing the face of forestry, Journal of Forestry. V 93, (12) : 30-33
TJ International Product Literature.

**CURVE CUT LUMBER**

Curve cut lumber products which use computer controlled thin curve cutting saws can produce lumber from logs formerly considered unmarketable. This technology may increase the market for the current low value hardwoods in New Hampshire but its introduction is likely to be slower than the introduction of laminate and oriented strand dimensional lumber. Prospects are long-term not short-term.
References: Personal communication Ken Skog, USFS Forest Products Research Laboratory, Madison, WI.

**DENSIFIED FIRE LOG PRODUCTS:**

Artificial logs are made from wood chips saw dust and shavings. Recycled construction and demolition waste wood is available with negative raw material cost. Prospects for using wood chips in this product seem poor in competition with recycled wood which is still in good supply in urban areas. The product also competes directly with firewood and therefore there seems little prospect of a large market developing.

References: RSG research for clients.

**ETHANOL/METHANOL FROM WOOD**

Our research indicates that there are no commercial ethanol from wood plants in operation in the US at present. An ethanol plant in Washington integrated with a pulp mill has been in operation since 1945 and an existing corn ethanol plant in Louisiana is planned for conversion to baggasse which is chemically similar to hardwood. These two plants, however, are special cases and they do not indicate that wood to ethanol is a viable commercial technology at present. The proposed ethanol plant in Alexandria, NH is unlikely to be built, although some other biomass facility may be constructed at the site. Methanol from wood appears to be an unlikely commercial prospect at present for fuel technology reasons as well as production cost reasons. The ethanol industry in general is very strongly influenced by federal government policy on gasoline additives and tax subsidies. Therefore the situation could change.

References: Personal communications Ken Skog USFS Forest Products Research Laboratory Madison WI. And Lee Lynd, Associate Professor of Engineering, Dartmouth College, Hanover NH.

**HIGH VALUE CHEMICALS**:

Many high value chemicals including Levulinic Acid and fuel additives can be made from wood. This has been heavily researched and in most cases paper, paper waste or pulping waste are lower cost raw materials. Current research/development includes Biofine Inc.and NYSERDA. In the long –term the prospects for chemicals are good but in the short-term the prospects are poor because the chemicals market if it develops is likely to be based on low cost recycled materials.

References: Personal communications Ken Skog USFS Forest Products Research Laboratory Madison WI, and NYSERDA.

**WOOD CHIP MULCH:**

Growing popularity of wood mulch has led to some use of harvested wood chips as mulch. Products include standard bark mulch substitutes and fine mulch used in hydro seeding. Products include blends of wood chips, recycled newsprint and polymer tackifiers. Products for turf improvement also sold. These markets could be substantial if the market value of "natural wood" is sufficient to overcome the higher cost of harvested chips. Wood chip mulch can also be used to stabilize erodible soils, roads and parking areas. Re-Fiber brand by "Wood Recycling Inc." Wobum, MA 800-982-8732 is a leader in this field. Prospects are good but the total volume is not likely to be large.

Reference: Re-Fiber Product Information.

**WOOD CHIPS AS MEDIUM FOR BIOFILTERS AND WASTE WATER PROCESSING**

Wood chips are used as an organic medium in biofilters for treating sewage effluent, septage and organic odors from landfills. Many new treatment facilities in New England are specifying biofilters for odor control and hazardous air emissions treatment. Wood chips are one of the products used in these treatment facilities. The total volume of chips required is small at present but this is a strong growth area. The size of the potential market is uncertain.

References: RSG research on biofilters for clients.

**WOOD CHIPS AS A COMPOST ADDITIVE FOR BIOSOLIDS**

Wood chips provide an excellent high carbon additive for composting biosolids from sewage treatment facilities. This is a growth area and harvested natural chips are preferred as the resulting compost is of higher quality. Total volumes in demand are however likely to be small.

References: SERBEP, 1994, A source book on wood waste recovery and recycling in the

Southeast, TVA Muscle Shoals AL., Section IV, Current and potential end uses for recycled wood.

## BIOPULPING

Hard wood chips can be made into pulp at apparently lower cost with biopulping pretreatment using fungi. Prospects in New England are moderate but cooperation with a pulp mill would be needed.. Chip exports for pulp are also a possibility with in-hold pretreatment. This technology seems promising and is under study.

References: Personal communication: Ken Skog, USFS Forest Products Research Laboratory, Madison WI

## LANDFILL COVER

Wood chips provide excellent daily cover for sanitary landfills and they have been used for this purpose. The cost however is usually much higher than earth or sand cover which is typically available on site. Wood chips from waste have been used as cover where there was a need for landfill disposal but that is not a market for harvested wood chips. Prospects for this product are poor.

References: SERBEP, 1994, A source book on wood waste recovery and recycling in the Southeast, TVA Muscle Shoals AL., Section IV, Current and potential end uses for recycled wood.

### General Observations

In general our research suggest that there are few short-term replacement markets for hardwood chips which would have anything like the volume currently being consumed in wood-fired power plants. Most of the markets researched are small, prefer softwood or are likely to start with manufacturing wood wastes or recycled biomass. In the intermediate to longer term, chemicals, ethanol, OSB, MDF, and oriented strand dimensional lumber are the most promising uses for low value hardwoods. In the long-term composite building materials are likely to dominate the wood products industry and New Hampshire will ultimately benefit from the change.

The most promising areas for further market research seem to be composite fiber products including OSB and oriented strand dimensional lumber and chemicals including ethanol. These all have high added value. Wood/concrete, wood/plastic and various uses for wood chips in mulch and pollution control may be worth investigating to determine the size of the potential market.

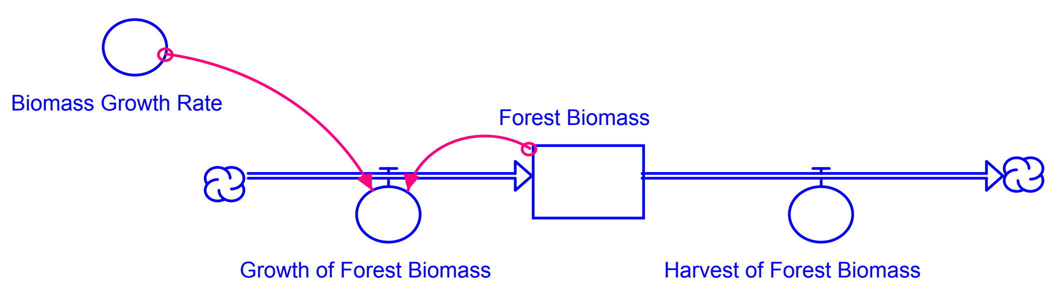
# Appendix B
## Stella Model Description

To model the change in timber inventories the STELLA programming environment was used. This modeling process enables the creation of a set of mathematical relationships to replicate history (e.g. the change in inventory volumes of White Pine in New Hampshire from 1973 to 1997) or to project future changes in inventories subject to assumptions of inflow and outflow.

The purpose of this section is to provide a brief overview of the modeling approach used in this analysis.

Figure 1 shows a generic forest growth structure.

***Figure 1: Generic Forest Growth and Harvest Structure***



In Figure 1, the rectangle represents *stocking* or *level* (mathematically, an integral equation). Figure 1 shows a stock of forest biomass (non-species specific). The rectangle represents the amount of biomass in the forest at any point in time. Stocks are assigned an initial condition, which for this analysis was the total growing stock biomass, by species, as estimated in 1997 from the recent USDA Forest Service Forest Inventory and Analysis (FIA).

Inventories increase or decrease depending on the rates (valves) that are connected to them. Mathematically valves are differentials. This object is much like a plumber's valve that opens or closes depending on physical conditions. When the valve opens, biomass will 'flow' into the level. In Figure 1 the stock of forest biomass is affected by 2 rates of flow: growth and harvest.[74]

The "Growth of Forest Biomass" represents the accumulation of cellulosic biomass in trees. This inflow is a product of the stock of forest biomass (it takes trees to grow trees) and a "Biomass Growth Rate", which is expressed as a fraction.

The "Biomass Growth Rate" is in a circle. Circles are called converters. They convert inputs to outputs. A converter may include an equation, a logical statement, or a numerical relationship between two variables. Converters do not accumulate but change instantaneously over the simulation run.

A *cloud* represents a source or a sink. An arrow pointing into a cloud is a sink; an arrow pointing away from a cloud is a source. In Figure 1, the cloud that precedes "Growth of Forest Biomass" is a source. The source cloud represents all of the necessary inputs to forest growth: soil, sunlight, water.

Solid arrows are referred to as *connectors* or information flows, and function to depict causal linkages among variables in the model. Connectors have no numerical value. The growth rate (Growth of Forest Biomass) is set within the converter and passed from the converter to the valve via the connector.

For the forest growth model used in this analysis, a generic model including all key rates of flow – accretion, ingrowth, cull, mortality, and harvest – was parameterized, by species, using data from the 1973, 1983, and 1997 New Hampshire Forest Inventories. Future projections used the same set of relationships, and the same parameters.

[74] In the actual model used for this analysis, several other rates of flow were used: ingrowth, accretion, cull, mortality, etc.

# Appendix C
## Stella Model Run Results

Table 1 lists the abbreviation, description, and units of key terms used in this model. Total Growing Stock (TGS) is the sum of Sawtimber Growing Stock (SGS) and Non-Sawtimber Growing Stock (NSGS). As shown, all terms are represented in million cubic feet (MMCF). Data sources listed SGS in thousand board feet (MBF). Hence, SGS was converted from MBF to MMCF using the International ¼ Inch Conversion (0.12299 cubic feet per board foot).[75]

Table 1. Description of key terms.

| Abbreviation | Description | Units |
|---|---|---|
| TGS | Total Growing Stock of Trees | MMCF |
| SGS | Sawtimber Growing Stock of Trees | MMCF |
| NSGS | Non-Sawtimber Growing Stock of Trees | MMCF |

The volume of SGS and NSGS for a given timber species is calculated as a function of the rate of removal, cull, accretion, and ingrowth for that species. These four processes are represented in million cubic feet per year (MMCF/YR) in the model. Definitions of these processes are listed in the New Hampshire Forest Statistics Report (FSR) and are now restated for clarity. [76]

> **Removals.** The net growing-stock (SGS or NSGS) volume harvested in logging, and forestry improvement operations—based on primary processor consumption.[77]

> **Cull (cull increment).** The net volume of growing-stock trees (SGS or NSGS) on the previous inventory that became rough or rotten trees in the current inventory, divided by the number of growing seasons between surveys.

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[75] Frieswyk, T.S. and Malley, A.M. *Forest Statistics for New Hampshire 1973 and 1983*. United States Department of Agriculture Forest Service, Northeastern Station. Resource Bulletin NE-88. June, 1985.

[76] Frieswyk, T.S. and Malley, A.M. *Forest Statistics for New Hampshire 1973 and 1983*. United States Department of Agriculture Forest Service, Northeastern Station. Resource Bulletin NE-88. June, 1985.

[77] This information is from a companion survey to the FIA process of the USDA Forest Service. This effort surveyed timber utilized by primary processors in New Hampshire and nearby markets that draw on wood from NH forests as a way to estimate removals. Removal data collected as part of the survey plot sampling process within the FIA was not used due to the inaccuracies associated with that source. This data is from observing cut stumps once every measurement period. Using averages for a year period based on data points 15 years apart is problematic given harvesting volume changes over this extended period of time.

**Accretion.** The estimated net growth on growing-stock trees (SGS or NSGS) that were measured during the previous inventory, divided by the number of growing seasons between surveys. It does not include the growth on trees that were cut during the period, nor those trees that died.

**Ingrowth (NSGS).** The estimated net volume of growing-stock trees (NSGS) that became 5.0 inches diameter breast height (d.b.h.) or larger during the period between inventories, divided by the number of growing seasons between surveys.

**Ingrowth (SGS).** The estimated net volume of growing-stock trees (SGS) that became 9.0 inches d.b.h. (softwoods) or 11.0 inches d.b.h. (hardwoods) or larger during the period between inventories, divided by the number of growing seasons between surveys.

### Calibration Results

The volume of NSGS and SGS were calibrated for a 14 year time period (1983 to 1997) for the following timber species: Balsam Fir (BF), Red Spruce (RS), White Pine (WP), Hemlock (H), and Other Softwoods (OS), Sugar Maple (SM), Red Maple (RM), Yellow Birch (YB), Paper Birch (PB), Beech (B), White Ash (WA), Aspen (A), Red Oak (RO), and Other Hardwoods (OH). Model calibration was conducted with historic data from the following sources.[78]

- ▲ Forest Statistics Report (FSR)
- ▲ Forest Inventory Analysis (FIA) Data Set
- ▲ Timber Product Output (TPO) Database

Initial (or 1983) and final (or 1997) volumes were taken from the FSR and FIA respectively. Average annual cull, ingrowth, and accretion were also taken from the FIA with average annual removals taken from the TPO. It should be noted that TPO data represents just 1996, while the FIA data represents 1982 to 1997; therefore, the 1996 data were assumed representative of the entire calibration period. The purpose of the calibration runs was to verify that the model is a likely good future predicting tool using known historical data.

Calibration was conducted by plotting model predicted and historic timber volumes of NSGS and SGS for each tree species over the 14 year calibration period. Level of agreement between corresponding predicted and historic plots was visually assessed to determine

78 Data for additional hardwood and softwood timber species existed, but information regarding each of these species was not explicitly needed. Consequently, data representing these species were lumped into the *Other Softwoods* and *Other Hardwoods* categories. All these data sources are from USDA Forest Service surveys and plot sampling.

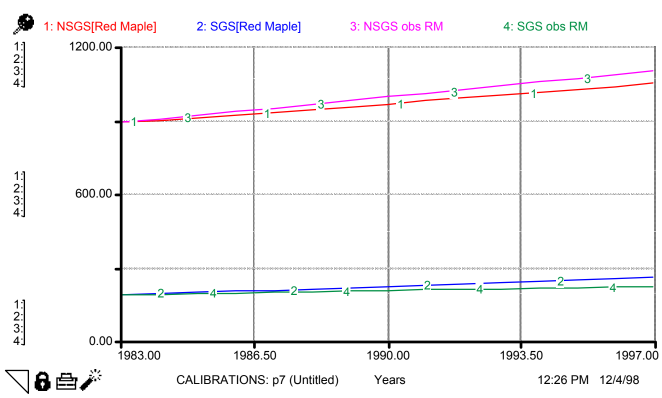
success of calibration. Hence, plots having a high level of agreement were deemed *well calibrated*. Conversely, plots having a low level of agreement were deemed *poorly calibrated*.

Agreement was high for all species except Balsam Fir, Hemlock, and Red Oak. Consequently, model parameter values for these species were re-checked for accuracy and adjusted where needed.

Discrepancy between predicted and historic plots is due to a scarcity of data. Discrete volumes of cull, removals, ingrowth, and accretion for each year in the calibration period were not available. However, average annual values for the entire calibration period were available.[79] Consequently, the model was calibrated with average annual values which limited its ability to imitate annual fluctuations of timber growth.

Figure 1 is an sample calibration plot of volume (MMCF) versus time (Years) assuming 100% initial availability of TGS. In this plot, curves one and three are predicted and historic volumes of Red Maple NSGS. Curves two and four are predicted and historic volumes of Red Maple SGS. As shown, both sets of curves exhibit very similar shape and magnitude.

Figure 1. Example calibration plot.




The datasets used for the modeling process and referenced above are listed in the following tables:

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[79] As an example, average annual accretion for a given time period would be the total volume of accretion in the time period divided by the number of growing seasons between the initial and final surveys taken during the time period.

## Table 2. Initial Total Growing Stock, Non-Sawtimber Growing Stock, and Sawtimber Growing Stock Stocking Values.

### *INITIAL STOCKING VALUES*

| Source | For Stats 73-83 | Prel Stats | For Stats 73-83 | Prel Stats | Conv | Conv | Calc | Calc |
|---|---|---|---|---|---|---|---|---|
| Units | MMCF | MMCF | MMBF | MMBF | MMCF | MMCF | MMCF | MMCF |
| Stock Type | 1983 TGS | 1997 TGS | 1983 SGS | 1997 SGS | 1983 SGS | 1997 SGS | 1983 NSGS | 1997 NSGS |
| **SOFTWOODS** | | | | | | | | |
| Balsam Fir | 616.1 | 483.0 | 1062.2 | 803.7 | 130.5 | 98.8 | 485.6 | 384.2 |
| Red spruce | 597.5 | 495.4 | 1329.8 | 1308.6 | 163.4 | 160.8 | 434.1 | 334.6 |
| White pine | 1528.9 | 1870.5 | 5209.8 | 7576.3 | 640.2 | 931.1 | 888.7 | 939.4 |
| Hemlock | 563.7 | 827.9 | 1522.7 | 2513.3 | 187.1 | 308.9 | 376.6 | 519.0 |
| Tamarack | 10.2 | 8.6 | 20.9 | 20.6 | 2.6 | 2.5 | 7.6 | 6.1 |
| White spruce | 31.5 | 37.1 | 59.8 | 120.1 | 7.3 | 14.8 | 24.2 | 22.3 |
| Black spruce | 5.3 | 0.1 | 3.8 | | 0.5 | 0.0 | 4.8 | 0.1 |
| Red pine | 46.0 | 42.6 | 184.2 | 162.0 | 22.6 | 19.9 | 23.4 | 22.7 |
| Northern white-cedar | 9.2 | 14.4 | 18.6 | 28.4 | 2.3 | 3.5 | 6.9 | 10.9 |
| Other | 39.3 | 41.5 | 96.8 | 120.9 | 11.9 | 14.9 | 27.4 | 26.6 |
| Other softwoods | 141.5 | 144.3 | 384.1 | 452.0 | 47.2 | 55.5 | 94.3 | 88.8 |
| TOTAL SOFTWOODS | 3447.7 | 3821.1 | 9508.6 | 12653.9 | 1168.5 | 1555.0 | 2279.2 | 2266.1 |
| **HARDWOODS** | | | | | | | | |
| Sugar maple | 651.0 | 763.5 | 1521.9 | 2011.3 | 187.0 | 247.2 | 464.0 | 516.3 |
| Red maple | 1067.3 | 1314.4 | 1467.6 | 1744.6 | 180.4 | 214.4 | 886.9 | 1100.0 |
| Yellow Birch | 453.8 | 472.4 | 1042.8 | 1033.0 | 128.1 | 126.9 | 325.7 | 345.5 |
| Paper birch | 565.7 | 506.7 | 680.7 | 687.5 | 83.7 | 84.5 | 482.0 | 422.2 |
| Beech | 384.3 | 440.1 | 1001.7 | 969.6 | 123.1 | 119.2 | 261.2 | 320.9 |
| White ash | 232.0 | 271.9 | 497.6 | 683.7 | 61.2 | 84.0 | 170.8 | 187.9 |
| Aspen | 276.9 | 255.4 | 483.6 | 537.0 | 59.4 | 66.0 | 217.5 | 189.4 |
| Red oaks | 657.6 | 877.9 | 1446.6 | 2303.5 | 177.8 | 283.1 | 479.8 | 594.8 |
| Gray Birch | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Black ash | 15.6 | 5.1 | 16.0 | 0.0 | 2.0 | 0.0 | 13.6 | 5.1 |
| White oaks | 72.6 | 75.5 | 159.1 | 194.3 | 19.6 | 23.9 | 53.0 | 51.6 |
| Basswood | 17.8 | 18.7 | 38.4 | 48.5 | 4.7 | 6.0 | 13.1 | 12.7 |
| Elm | 14.2 | 9.2 | 35.0 | 16.6 | 4.3 | 2.0 | 9.9 | 7.2 |
| Other | 147.7 | 188.9 | 181.6 | 265.6 | 22.3 | 32.6 | 125.4 | 156.3 |
| Other hardwoods | 267.9 | 297.4 | 430.1 | 525.0 | 52.9 | 64.5 | 215.0 | 232.9 |
| TOTAL HARDWOODS | 4556.5 | 5199.7 | 8572.6 | 10495.2 | 1053.5 | 1289.8 | 3503.0 | 3909.9 |
| GRAND TOTAL | 8004.2 | 9020.8 | 18081.2 | 23149.1 | 2222.0 | 2844.8 | 5782.2 | 6176.0 |

## Table 3. Accretion volumes and rates.

### *ACCRETION VALUES*

| Source | Prel Stats | Conv | Prel Stats | Conv | Calc | Calc | Calc |
|---|---|---|---|---|---|---|---|
| Units | MCF | MMCF | MBF | MMCF | MMCF | NONE | NONE |
| Stock Type | 82-97 TGS | 82-97 TGS | 82-97 SGS | 82-97 SGS | 82-97 NSGS | 82-97 SGS | 82-97 NSGS |
| **SOFTWOODS** | | | | | | | |
| **Balsam Fir** | 7234.0 | 7.2 | 10450.0 | 1.3 | 5.9 | 0.011 | 0.014 |
| **Red spruce** | 7257.0 | 7.3 | 22363.0 | 2.7 | 4.5 | 0.017 | 0.012 |
| **White pine** | 32710.0 | 32.7 | 158312.0 | 19.5 | 13.3 | 0.025 | 0.015 |
| **Hemlock** | 11242.0 | 11.2 | 37711.0 | 4.6 | 6.6 | 0.019 | 0.015 |
| **Tamarack** | 243.0 | 0.2 | 595.0 | 0.1 | 0.2 | 0.029 | 0.025 |
| **White spruce** | 549.0 | 0.5 | 2303.0 | 0.3 | 0.3 | 0.026 | 0.011 |
| **Black spruce** | 31.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.000 | 0.013 |
| **Red pine** | 255.0 | 0.3 | 1299.0 | 0.2 | 0.1 | 0.008 | 0.004 |
| **Northern white-cedar** | 251.0 | 0.3 | 1485.0 | 0.2 | 0.1 | 0.063 | 0.008 |
| **Other** | 350.0 | 0.4 | 1638.0 | 0.2 | 0.1 | 0.015 | 0.006 |
| **Other Softwoods** | 1679.0 | 1.7 | 7320.0 | 0.9 | 0.8 | 0.023 | 0.011 |
| **TOTAL SOFTWOODS** | 60122.0 | 60.1 | 236156.0 | 29.0 | 31.1 | 0.021 | 0.012 |
| **HARDWOODS** | | | | | | | |
| **Sugar maple** | 9832.0 | 9.8 | 15938.0 | 2.0 | 7.9 | 0.009 | 0.016 |
| **Red maple** | 17995.0 | 18.0 | 21301.0 | 2.6 | 15.4 | 0.013 | 0.015 |
| **Yellow Birch** | 4618.0 | 4.6 | 8039.0 | 1.0 | 3.6 | 0.008 | 0.011 |
| **Paper Birch** | 4467.0 | 4.5 | 3063.0 | 0.4 | 4.1 | 0.004 | 0.009 |
| **Beech** | 5062.0 | 5.1 | 10000.0 | 1.2 | 3.8 | 0.010 | 0.013 |
| **White ash** | 4350.0 | 4.4 | 9523.0 | 1.2 | 3.2 | 0.016 | 0.018 |
| **Aspen** | 3372.0 | 3.4 | 6583.0 | 0.8 | 2.6 | 0.013 | 0.013 |
| **Red oaks** | 9229.0 | 9.2 | 26384.0 | 3.2 | 6.0 | 0.014 | 0.011 |
| **Gray Birch** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 |
| **Black ash** | 17.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.000 | 0.002 |
| **White oaks** | 814.0 | 0.8 | 1399.0 | 0.2 | 0.6 | 0.008 | 0.012 |
| **Basswood** | 427.0 | 0.4 | 1268.0 | 0.2 | 0.3 | 0.029 | 0.021 |
| **Elm** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 |
| **Other** | 2468.0 | 2.5 | 2120.0 | 0.3 | 2.2 | 0.009 | 0.016 |
| **Other hardwoods** | 3726.0 | 3.7 | 4787.0 | 0.6 | 3.1 | 0.008 | 0.008 |
| **TOTAL HARDWOODS** | 62651.0 | 62.7 | 105618.0 | 13.0 | 49.7 | 0.009 | 0.011 |
| **GRAND TOTAL** | 122773.0 | 122.8 | 341774.0 | 42.0 | 80.8 | 0.015 | 0.012 |

## Table 4. Ingrowth volumes and rates.

### *INGROWTH VALUES*

| Source | Prel Stats | Conv | Prel Stats | Prel Stats | Conv | Calc | Calc |
|---|---|---|---|---|---|---|---|
| Units | MCF | MMCF | MBF | MMCF | MMCF | NONE | NONE |
| Stock Type | 82-97 TGS | 82-97 TGS | 82-97 SGS | 82-97 SGS | 82-97 NSGS | 82-97 SGS | 82-97 NSGS |
| **SOFTWOODS** | | | | | | | |
| **Balsam Fir** | 10271.0 | 10.3 | 22814.0 | 2.8 | 7.5 | 0.006 | 0.017 |
| **Red spruce** | 4368.0 | 4.4 | 16850.0 | 2.1 | 2.3 | 0.005 | 0.006 |
| **White pine** | 12952.0 | 13.0 | 65723.0 | 8.1 | 4.9 | 0.009 | 0.005 |
| **Hemlock** | 8476.0 | 8.5 | 26188.0 | 3.2 | 5.3 | 0.007 | 0.012 |
| **Tamarack** | 155.0 | 0.2 | 585.0 | 0.1 | 0.1 | 0.010 | 0.012 |
| **White spruce** | 369.0 | 0.4 | 1872.0 | 0.2 | 0.1 | 0.010 | 0.006 |
| **Black spruce** | 0.0 | 0.0 | 101.0 | 0.0 | 0.0 | 0.005 | -0.005 |
| **Red pine** | 582.0 | 0.6 | 109.0 | 0.0 | 0.6 | 0.001 | 0.025 |
| **Northern white-cedar** | 115.0 | 0.1 | 351.0 | 0.0 | 0.1 | 0.005 | 0.008 |
| **Other** | 220.0 | 0.2 | 616.0 | 0.1 | 0.1 | 0.003 | 0.005 |
| **Other softwoods** | 1441.0 | 1.4 | 3634.0 | 0.4 | 1.0 | 0.006 | 0.009 |
| **TOTAL SOFTWOODS** | **37508.0** | **37.5** | **135209.0** | **16.6** | **20.9** | **0.006** | **0.009** |
| **HARDWOODS** | | | | | | | |
| **Sugar maple** | 6651.0 | 6.7 | 28569.0 | 3.5 | 3.1 | 0.007 | 0.006 |
| **Red maple** | 11206.0 | 11.2 | 43436.0 | 5.3 | 5.9 | 0.005 | 0.006 |
| **Yellow Birch** | 4306.0 | 4.3 | 16496.0 | 2.0 | 2.3 | 0.006 | 0.007 |
| **Paper Birch** | 3853.0 | 3.9 | 16603.0 | 2.0 | 1.8 | 0.005 | 0.004 |
| **Beech** | 3996.0 | 4.0 | 19082.0 | 2.3 | 1.7 | 0.008 | 0.006 |
| **White ash** | 3908.0 | 3.9 | 15163.0 | 1.9 | 2.0 | 0.010 | 0.011 |
| **Aspen** | 2949.0 | 2.9 | 17828.0 | 2.2 | 0.8 | 0.011 | 0.004 |
| **Red oaks** | 8403.0 | 8.4 | 46305.0 | 5.7 | 2.7 | 0.011 | 0.005 |
| **Gray Birch** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 |
| **Black ash** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 |
| **White oaks** | 555.0 | 0.6 | 2229.0 | 0.3 | 0.3 | 0.005 | 0.005 |
| **Basswood** | 219.0 | 0.2 | 1029.0 | 0.1 | 0.1 | 0.010 | 0.007 |
| **Elm** | 48.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.000 | 0.006 |
| **Other** | 2255.0 | 2.3 | 7091.0 | 0.9 | 1.4 | 0.006 | 0.010 |
| **Other hardwoods** | 3077.0 | 3.1 | 10349.0 | 1.3 | 1.8 | 0.004 | 0.005 |
| **TOTAL HARDWOODS** | **47527.0** | **47.5** | **210573.0** | **25.9** | **21.6** | **0.006** | **0.005** |
| **GRAND TOTAL** | **85035.0** | **85.0** | **345782.0** | **42.5** | **42.5** | **0.006** | **0.007** |

## Table 5. Cull volumes and rates.

### *CULL VALUES*

| Source | Prel Stats | Conv | Prel Stats | Prel Stats | Conv | Calc | Calc |
|---|---|---|---|---|---|---|---|
| Units | MCF | MMCF | MBF | MMCF | MMCF | NONE | NONE |
| Stock Type | 82-97 TGS | 82-97 TGS | 82-97 SGS | 82-97 SGS | 82-97 NSGS | 82-97 SGS | 82-97 NSGS |
| **SOFTWOODS** | | | | | | | |
| Balsam Fir | 321.0 | 0.3 | 108.0 | 0.0 | 0.3 | 0.000 | 0.001 |
| Red spruce | 534.0 | 0.5 | 1532.0 | 0.2 | 0.3 | 0.001 | 0.001 |
| White pine | 2472.0 | 2.5 | 9603.0 | 1.2 | 1.3 | 0.002 | 0.001 |
| Hemlock | 3303.0 | 3.3 | 11404.0 | 1.4 | 1.9 | 0.006 | 0.004 |
| Tamarack | 80.0 | 0.1 | 0.0 | 0.0 | 0.1 | 0.000 | 0.012 |
| White spruce | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 |
| Black spruce | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 |
| Red pine | 72.0 | 0.1 | 309.0 | 0.0 | 0.0 | 0.002 | 0.001 |
| Northern white-cedar | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 |
| Other | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 |
| Other Softwoods | 152.0 | 0.2 | 309.0 | 0.0 | 0.1 | 0.000 | 0.002 |
| **TOTAL SOFTWOODS** | **6782.0** | **6.8** | **22956.0** | **2.8** | **4.0** | **0.001** | **0.002** |
| **HARDWOODS** | | | | | | | |
| Sugar maple | 2127.0 | 2.1 | 6601.0 | 0.8 | 1.3 | 0.004 | 0.003 |
| Red maple | 3855.0 | 3.9 | 9326.0 | 1.1 | 2.7 | 0.006 | 0.003 |
| Yellow Birch | 2055.0 | 2.1 | 5192.0 | 0.6 | 1.4 | 0.005 | 0.004 |
| Paper Birch | 1915.0 | 1.9 | 3483.0 | 0.4 | 1.5 | 0.005 | 0.003 |
| Beech | 2977.0 | 3.0 | 7101.0 | 0.9 | 2.1 | 0.007 | 0.007 |
| White ash | 87.0 | 0.1 | 0.0 | 0.0 | 0.1 | 0.000 | 0.000 |
| Aspen | 175.0 | 0.2 | 491.0 | 0.1 | 0.1 | 0.001 | 0.001 |
| Red oaks | 236.0 | 0.2 | 601.0 | 0.1 | 0.2 | 0.000 | 0.000 |
| Gray Birch | 0.0 | | | | | | |
| Black ash | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 |
| White oaks | 123.0 | 0.1 | 580.0 | 0.1 | 0.1 | 0.003 | 0.001 |
| Basswood | 32.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.000 | 0.002 |
| Elm | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 |
| Other | 326.0 | 0.3 | 850.0 | 0.1 | 0.2 | 0.004 | 0.002 |
| Other Hardwoods | 481.0 | 0.5 | 1430.0 | 0.2 | 0.3 | 0.001 | 0.001 |
| **TOTAL HARDWOODS** | **13908.0** | **13.9** | **34225.0** | **4.2** | **9.7** | **0.003** | **0.002** |
| **GRAND TOTAL** | **20690.0** | **20.7** | **57181.0** | **7.0** | **13.7** | **0.002** | **0.002** |

## Table 6. Removal (harvest) volumes and rates.

### *REMOVAL VALUES*

| Source | Prel Stats | Conv | Prel Stats | Prel Stats | Conv | Calc | Calc |
|---|---|---|---|---|---|---|---|
| Units | MCF | MMCF | MBF | MMCF | MMCF | NONE | NONE |
| Stock Type | 97 TGS | 97 TGS | 97 SGS | 97 SGS | 97 NSGS | 97 SGS | 97 NSGS |
| **SOFTWOODS** | | | | | | | |
| Balsam Fir (true fir) | 4677.0 | 4.7 | 3841.0 | 0.5 | 4.2 | 0.004 | 0.010 |
| Red spruce | 4776.4 | 4.8 | 4327.7 | 0.5 | 4.2 | 0.003 | 0.011 |
| White pine | 13930.0 | 13.9 | 38927.0 | 4.8 | 9.1 | 0.006 | 0.010 |
| Hemlock | 7863.0 | 7.9 | 7881.0 | 1.0 | 6.9 | 0.004 | 0.015 |
| Tamarack | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 |
| White spruce | 319.7 | 0.3 | 309.1 | 0.0 | 0.3 | 0.003 | 0.012 |
| Black spruce | 194.8 | 0.2 | 188.4 | 0.0 | 0.2 | 0.099 | 0.070 |
| Red pine | 168.0 | 0.2 | 6.0 | 0.0 | 0.2 | 0.000 | 0.007 |
| Northern white-cedar | 5.0 | 0.0 | 21.0 | 0.0 | 0.0 | 0.001 | 0.000 |
| Other | 1096.0 | 1.1 | 3377.0 | 0.4 | 0.7 | 0.031 | 0.025 |
| Other softwoods | 1783.5 | 1.8 | 3901.5 | 0.5 | 1.3 | 0.022 | 0.019 |
| **TOTAL SOFTWOODS** | **33029.9** | **33.0** | **58878.2** | **7.2** | **25.8** | **0.016** | **0.016** |
| **HARDWOODS** | | | | | | | |
| Sugar maple | 424.0 | 0.4 | 1840.0 | 0.2 | 0.2 | 0.001 | 0.000 |
| Red maple | 2050.0 | 2.1 | 8959.0 | 1.1 | 0.9 | 0.006 | 0.001 |
| Yellow Birch | 1265.0 | 1.3 | 5522.0 | 0.7 | 0.6 | 0.005 | 0.002 |
| Paper Birch | 937.0 | 0.9 | 4068.0 | 0.5 | 0.4 | 0.006 | 0.001 |
| Beech | 528.0 | 0.5 | 2308.0 | 0.3 | 0.2 | 0.002 | 0.001 |
| White ash | 757.7 | 0.8 | 3303.0 | 0.4 | 0.4 | 0.006 | 0.002 |
| Aspen | 584.0 | 0.6 | 882.0 | 0.1 | 0.5 | 0.002 | 0.002 |
| Red oaks | 10122.0 | 10.1 | 44252.0 | 5.4 | 4.7 | 0.024 | 0.009 |
| Gray Birch | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 |
| Black ash | 24.2 | 0.0 | 105.7 | 0.0 | 0.0 | 0.013 | 0.001 |
| White oaks | 107.0 | 0.1 | 469.0 | 0.1 | 0.0 | 0.003 | 0.001 |
| Basswood | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 |
| Elm | 4.0 | 0.0 | 15.0 | 0.0 | 0.0 | 0.001 | 0.000 |
| Other | 37371.0 | 37.4 | 20279.0 | 2.5 | 34.9 | 0.091 | 0.248 |
| Other hardwoods | 37506.2 | 37.5 | 20868.7 | 2.6 | 34.9 | 0.018 | 0.042 |
| **TOTAL HARDWOODS** | **54173.9** | **54.2** | **92002.7** | **11.3** | **42.9** | **0.012** | **0.021** |
| **GRAND TOTAL** | **87203.8** | **87.2** | **150880.9** | **18.5** | **68.7** | **0.014** | **0.018** |

### Simulation Results

Following calibration, the model was run for a 32 year time period (1983 to 2015). The time period was extended out to 2015 to assess the impact of wood chip removal reduction on NSGS and SGS volumes. To this end, four scenarios were simulated. The first two were conducted assuming 80% initial availability of TGS (or 0.8 multiplied by the initial volume) while the second two scenarios were conducted assuming 60% initial availability of TGS. A 1995 study[80] showed that: statutory and legal constraints; land ownership removals from the timber base; physical limitations; and small parcel limitations result in approximately 22% of the forested land base to be unavailable for harvesting. Additional lands, not as easily quantifiable, are not available for harvesting depending on landowner attitudes – which change over time.

[80] New Hampshire Forest Inventory Project – Timber Availability Analysis, June, 1995

Wood chip removal rates were varied for each scenario to account for a 20% reduction of wood chip removals over a one year period and a five year period (representing a buydown scenario) and 100% wood chip removal over the one and five-year period (representing closure of all wood energy plants). All wood chip removal reductions were begun in 1997. The four scenarios are summarized below.

- *Scenario 1*: 80% initial availability Total Growing Stock (TGS), 20% reduction in wood chip removals over a five year period (markets).
- *Scenario 2*: 60% initial availability of TGS , 20% reduction in wood chip removals over a five year period.
- *Scenario 3*: 80% initial availability of TGS, ramp wood chip removals down 100% over 1 year.
- *Scenario 4*: 60% initial availability of TGS, ramp wood chip removals down 100% over 1 year.

The results for each scenario are shown in the tables in Appendix D. The numbers in each table represent the actual volumes of net growth versus drain over the period ending in 2015[81]. Growth to drain ratios are also listed.

Appendix E contains model run data that is broken down by species.

[81] Net growth was calculated as the sum of ingrowth and accretion while drain was calculated as the sum of cull and removals.

# Appendix D

## Stella© Model Runs

## Scenario #1

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Stella Model Run - NH Timber Growth and Drain period 1983-2015** | | | | | | |
| | 80% Availability at 20% reduction in chip market over 5-year period beginning in 1997 | | | | | | |
| | **Net Growth** | | | **Drain** | | | |
| **TIME** | **TOT SW** | **TOT HW** | **GRAND TOTAL** | **TOT SW** | **TOT HW** | **GRAND TOTAL** | **Growth to** |
| **YEARS** | **MMCF** | **MMCF** | **MMCF** | **MMCF** | **MMCF** | **MMCF** | **Drain Ratio** |
| 1983 | 75.07 | 86.54 | 161.61 | 37.5 | 32.4 | 69.9 | 2.31268 |
| 1984 | 75.63 | 87.39 | 163.02 | 37.7 | 32.5 | 70.2 | 2.32189 |
| 1985 | 76.22 | 88.25 | 164.47 | 38.0 | 32.5 | 70.6 | 2.33059 |
| 1986 | 76.79 | 89.13 | 165.92 | 38.3 | 32.6 | 71.0 | 2.33789 |
| 1987 | 77.36 | 90.02 | 167.38 | 38.7 | 32.7 | 71.4 | 2.3459 |
| 1988 | 77.96 | 90.94 | 168.9 | 39.0 | 32.8 | 71.8 | 2.35368 |
| 1989 | 78.56 | 91.85 | 170.41 | 39.3 | 32.9 | 72.2 | 2.3609 |
| 1990 | 79.17 | 92.8 | 171.97 | 39.6 | 33.1 | 72.6 | 2.36775 |
| 1991 | 79.78 | 93.74 | 173.52 | 39.9 | 33.2 | 73.1 | 2.37406 |
| 1992 | 80.39 | 94.71 | 175.1 | 40.2 | 33.3 | 73.6 | 2.38069 |
| 1993 | 81.01 | 95.73 | 176.74 | 40.5 | 33.5 | 74.1 | 2.38644 |
| 1994 | 81.63 | 96.72 | 178.35 | 40.9 | 33.7 | 74.6 | 2.39171 |
| 1995 | 82.27 | 97.74 | 180.01 | 41.2 | 33.9 | 75.1 | 2.39821 |
| 1996 | 82.91 | 98.78 | 181.69 | 41.6 | 34.1 | 75.6 | 2.40299 |
| 1997 | 83.57 | 99.85 | 183.42 | 41.9 | 34.3 | 76.1 | 2.40898 |
| 1998 | 84.22 | 100.91 | 185.13 | 39.5 | 31.5 | 70.9 | 2.61004 |
| 1999 | 84.97 | 102.08 | 187.05 | 37.1 | 28.7 | 65.7 | 2.84617 |
| 2000 | 85.81 | 103.32 | 189.13 | 34.6 | 28.2 | 62.8 | 3.00971 |
| 2001 | 86.75 | 104.58 | 191.33 | 32.2 | 28.1 | 60.3 | 3.17087 |
| 2002 | 87.77 | 105.89 | 193.66 | 32.6 | 28.5 | 61.2 | 3.16645 |
| 2003 | 88.81 | 107.21 | 196.02 | 33.0 | 29.0 | 62.0 | 3.16212 |
| 2004 | 89.86 | 108.55 | 198.41 | 33.4 | 29.4 | 62.8 | 3.15889 |
| 2005 | 90.95 | 109.93 | 200.88 | 33.8 | 29.8 | 63.7 | 3.15601 |
| 2006 | 92.04 | 111.3 | 203.34 | 34.2 | 30.3 | 64.5 | 3.15207 |
| 2007 | 93.12 | 112.71 | 205.83 | 34.7 | 30.7 | 65.4 | 3.14821 |
| 2008 | 94.22 | 114.1 | 208.32 | 35.1 | 31.2 | 66.3 | 3.1435 |
| 2009 | 95.35 | 115.55 | 210.9 | 35.5 | 31.6 | 67.1 | 3.1412 |
| 2010 | 96.51 | 117.01 | 213.52 | 36.0 | 32.1 | 68.0 | 3.13862 |
| 2011 | 97.65 | 118.48 | 216.13 | 36.4 | 32.6 | 69.0 | 3.13414 |
| 2012 | 98.82 | 119.96 | 218.78 | 36.8 | 33.0 | 69.9 | 3.13124 |
| 2013 | 100.02 | 121.49 | 221.51 | 37.3 | 33.5 | 70.8 | 3.12823 |
| 2014 | 101.23 | 123.01 | 224.24 | 37.8 | 34.0 | 71.7 | 3.12573 |
| Final | 102.44 | 124.56 | 227 | 38.2 | 34.5 | 72.7 | 3.12156 |

SW=softwood HW=hardwood MMCF=Million cubic feet

# Scenario #2

| | Stella Model Run - NH Timber Growth and Drain period 1983-2015 | | | | | | |
|---|---|---|---|---|---|---|---|
| | 60% Availability at 20% reduction in chip market over 5-year period beginning in 1997 | | | | | | |
| | **Net Growth** | | | **Drain** | | | |
| **TIME** | **TOT SW** | **TOT HW** | **GRAND TOTAL** | **TOT SW** | **TOT HW** | **GRAND TOTAL** | **Growth to** |
| **YEARS** | **MMCF** | **MMCF** | **MMCF** | **MMCF** | **MMCF** | **MMCF** | **Drain Ratio** |
| 1983 | 56.31 | 64.91 | 121.22 | 36.24 | 29.73 | 65.97 | 1.8375 |
| 1984 | 56.49 | 65.44 | 121.93 | 36.5 | 29.74 | 66.24 | 1.84073 |
| 1985 | 56.68 | 65.99 | 122.67 | 36.77 | 29.77 | 66.54 | 1.84355 |
| 1986 | 56.86 | 66.55 | 123.41 | 37.04 | 29.8 | 66.84 | 1.84635 |
| 1987 | 57.07 | 67.1 | 124.17 | 37.32 | 29.86 | 67.18 | 1.84832 |
| 1988 | 57.24 | 67.69 | 124.93 | 37.6 | 29.92 | 67.52 | 1.85027 |
| 1989 | 57.42 | 68.27 | 125.69 | 37.88 | 30 | 67.88 | 1.85165 |
| 1990 | 57.6 | 68.88 | 126.48 | 38.15 | 30.09 | 68.24 | 1.85346 |
| 1991 | 57.78 | 69.5 | 127.28 | 38.44 | 30.17 | 68.61 | 1.85512 |
| 1992 | 57.94 | 70.12 | 128.06 | 38.73 | 30.3 | 69.03 | 1.85514 |
| 1993 | 58.13 | 70.76 | 128.89 | 39.03 | 30.41 | 69.44 | 1.85613 |
| 1994 | 58.29 | 71.41 | 129.7 | 39.34 | 30.54 | 69.88 | 1.85604 |
| 1995 | 58.46 | 72.07 | 130.53 | 39.64 | 30.67 | 70.31 | 1.85649 |
| 1996 | 58.63 | 72.71 | 131.34 | 39.95 | 30.83 | 70.78 | 1.85561 |
| 1997 | 58.77 | 73.38 | 132.15 | 40.25 | 30.97 | 71.22 | 1.85552 |
| 1998 | 58.93 | 74.09 | 133.02 | 37.79 | 28.12 | 65.91 | 2.01821 |
| 1999 | 59.17 | 74.86 | 134.03 | 35.32 | 25.3 | 60.62 | 2.21099 |
| 2000 | 59.49 | 75.68 | 135.17 | 32.88 | 24.81 | 57.69 | 2.34304 |
| 2001 | 59.89 | 76.57 | 136.46 | 30.45 | 24.62 | 55.07 | 2.47794 |
| 2002 | 60.36 | 77.45 | 137.81 | 30.79 | 25 | 55.79 | 2.47016 |
| 2003 | 60.84 | 78.36 | 139.2 | 31.14 | 25.39 | 56.53 | 2.46241 |
| 2004 | 61.34 | 79.27 | 140.61 | 31.51 | 25.78 | 57.29 | 2.45436 |
| 2005 | 61.83 | 80.2 | 142.03 | 31.86 | 26.15 | 58.01 | 2.44837 |
| 2006 | 62.31 | 81.14 | 143.45 | 32.23 | 26.54 | 58.77 | 2.44087 |
| 2007 | 62.81 | 82.11 | 144.92 | 32.6 | 26.95 | 59.55 | 2.43359 |
| 2008 | 63.31 | 83.07 | 146.38 | 33 | 27.34 | 60.34 | 2.42592 |
| 2009 | 63.81 | 84.05 | 147.86 | 33.39 | 27.76 | 61.15 | 2.41799 |
| 2010 | 64.29 | 85.04 | 149.33 | 33.77 | 28.16 | 61.93 | 2.41127 |
| 2011 | 64.8 | 86.04 | 150.84 | 34.18 | 28.56 | 62.74 | 2.40421 |
| 2012 | 65.3 | 87.05 | 152.35 | 34.57 | 28.96 | 63.53 | 2.39808 |
| 2013 | 65.79 | 88.07 | 153.86 | 34.98 | 29.38 | 64.36 | 2.39062 |
| 2014 | 66.29 | 89.1 | 155.39 | 35.4 | 29.82 | 65.22 | 2.38255 |
| Final | 66.78 | 90.15 | 156.93 | 35.81 | 30.24 | 66.05 | 2.37593 |

SW=softwood HW=hardwood MMCF=Million cubic feet

# Scenario #3

| | Stella Model Run - NH Timber Growth and Drain period 1983-2015 | | | | | | |
|---|---|---|---|---|---|---|---|
| | 80% Availability at 100% reduction in chip market over 1-year period beginning in 1997 | | | | | | |
| | **Net Growth** | | | **Drain** | | | |
| **TIME** | **TOT SW** | **TOT HW** | **GRAND TOTAL** | **TOT SW** | **TOT HW** | **GRAND TOTAL** | **Growth to** |
| **YEARS** | **MMCF** | **MMCF** | **MMCF** | **MMCF** | **MMCF** | **MMCF** | **Drain Ratio** |
| 1983 | 75.07 | 86.54 | 161.61 | 37.46 | 32.42 | 69.88 | 2.31268 |
| 1984 | 75.63 | 87.39 | 163.02 | 37.74 | 32.47 | 70.21 | 2.32189 |
| 1985 | 76.22 | 88.25 | 164.47 | 38.04 | 32.53 | 70.57 | 2.33059 |
| 1986 | 76.79 | 89.13 | 165.92 | 38.34 | 32.63 | 70.97 | 2.33789 |
| 1987 | 77.36 | 90.02 | 167.38 | 38.65 | 32.7 | 71.35 | 2.3459 |
| 1988 | 77.96 | 90.94 | 168.9 | 38.95 | 32.81 | 71.76 | 2.35368 |
| 1989 | 78.56 | 91.85 | 170.41 | 39.25 | 32.93 | 72.18 | 2.3609 |
| 1990 | 79.17 | 92.8 | 171.97 | 39.57 | 33.06 | 72.63 | 2.36775 |
| 1991 | 79.78 | 93.74 | 173.52 | 39.89 | 33.2 | 73.09 | 2.37406 |
| 1992 | 80.39 | 94.71 | 175.1 | 40.21 | 33.34 | 73.55 | 2.38069 |
| 1993 | 81.01 | 95.73 | 176.74 | 40.54 | 33.52 | 74.06 | 2.38644 |
| 1994 | 81.63 | 96.72 | 178.35 | 40.88 | 33.69 | 74.57 | 2.39171 |
| 1995 | 82.27 | 97.74 | 180.01 | 41.21 | 33.85 | 75.06 | 2.39821 |
| 1996 | 82.91 | 98.78 | 181.69 | 41.55 | 34.06 | 75.61 | 2.40299 |
| 1997 | 83.57 | 99.85 | 183.42 | 41.89 | 34.25 | 76.14 | 2.40898 |
| 1998 | 84.22 | 100.91 | 185.13 | 28.35 | 26.43 | 54.78 | 3.37952 |
| 1999 | 85.31 | 102.18 | 187.49 | 28.72 | 26.84 | 55.56 | 3.37455 |
| 2000 | 86.4 | 103.47 | 189.87 | 29.09 | 27.23 | 56.32 | 3.37127 |
| 2001 | 87.52 | 104.8 | 192.32 | 29.5 | 27.66 | 57.16 | 3.36459 |
| 2002 | 88.64 | 106.13 | 194.77 | 29.89 | 28.07 | 57.96 | 3.36042 |
| 2003 | 89.79 | 107.46 | 197.25 | 30.29 | 28.47 | 58.76 | 3.35688 |
| 2004 | 90.94 | 108.84 | 199.78 | 30.69 | 28.88 | 59.57 | 3.3537 |
| 2005 | 92.11 | 110.21 | 202.32 | 31.12 | 29.31 | 60.43 | 3.34801 |
| 2006 | 93.29 | 111.63 | 204.92 | 31.53 | 29.75 | 61.28 | 3.34399 |
| 2007 | 94.5 | 113.04 | 207.54 | 31.96 | 30.2 | 62.16 | 3.3388 |
| 2008 | 95.72 | 114.47 | 210.19 | 32.39 | 30.66 | 63.05 | 3.3337 |
| 2009 | 96.96 | 115.93 | 212.89 | 32.83 | 31.12 | 63.95 | 3.32901 |
| 2010 | 98.23 | 117.4 | 215.63 | 33.28 | 31.58 | 64.86 | 3.32455 |
| 2011 | 99.5 | 118.91 | 218.41 | 33.72 | 32.04 | 65.76 | 3.32132 |
| 2012 | 100.78 | 120.45 | 221.23 | 34.17 | 32.53 | 66.7 | 3.31679 |
| 2013 | 102.09 | 121.97 | 224.06 | 34.63 | 32.98 | 67.61 | 3.31401 |
| 2014 | 103.42 | 123.53 | 226.95 | 35.11 | 33.47 | 68.58 | 3.30927 |
| Final | 104.77 | 125.1 | 229.87 | 35.59 | 33.97 | 69.56 | 3.30463 |

SW=softwood HW=hardwood MMCF=Million cubic feet

# Scenario #4

| | Stella Model Run - NH Timber Growth and Drain period 1983-2015 | | | | | | |
|---|---|---|---|---|---|---|---|
| | 60% Availability at 100% reduction in chip market over 1-year period beginning in 1997 | | | | | | |
| | **Net Growth** | | | **Drain** | | | |
| **TIME** | **TOT SW** | **TOT HW** | **GRAND TOTAL** | **TOT SW** | **TOT HW** | **GRAND TOTAL** | **Growth to** |
| **YEARS** | **MMCF** | **MMCF** | **MMCF** | **MMCF** | **MMCF** | **MMCF** | **Drain Ratio** |
| 1983 | 56.31 | 64.91 | 121.22 | 36.24 | 29.73 | 65.97 | 1.8375 |
| 1984 | 56.49 | 65.44 | 121.93 | 36.5 | 29.74 | 66.24 | 1.84073 |
| 1985 | 56.68 | 65.99 | 122.67 | 36.77 | 29.77 | 66.54 | 1.84355 |
| 1986 | 56.86 | 66.55 | 123.41 | 37.04 | 29.8 | 66.84 | 1.84635 |
| 1987 | 57.07 | 67.1 | 124.17 | 37.32 | 29.86 | 67.18 | 1.84832 |
| 1988 | 57.24 | 67.69 | 124.93 | 37.6 | 29.92 | 67.52 | 1.85027 |
| 1989 | 57.42 | 68.27 | 125.69 | 37.88 | 30 | 67.88 | 1.85165 |
| 1990 | 57.6 | 68.88 | 126.48 | 38.15 | 30.09 | 68.24 | 1.85346 |
| 1991 | 57.78 | 69.5 | 127.28 | 38.44 | 30.17 | 68.61 | 1.85512 |
| 1992 | 57.94 | 70.12 | 128.06 | 38.73 | 30.3 | 69.03 | 1.85514 |
| 1993 | 58.13 | 70.76 | 128.89 | 39.03 | 30.41 | 69.44 | 1.85613 |
| 1994 | 58.29 | 71.41 | 129.7 | 39.34 | 30.54 | 69.88 | 1.85604 |
| 1995 | 58.46 | 72.07 | 130.53 | 39.64 | 30.67 | 70.31 | 1.85649 |
| 1996 | 58.63 | 72.71 | 131.34 | 39.95 | 30.83 | 70.78 | 1.85561 |
| 1997 | 58.77 | 73.38 | 132.15 | 40.25 | 30.97 | 71.22 | 1.85552 |
| 1998 | 58.93 | 74.09 | 133.02 | 26.67 | 23.09 | 49.76 | 2.67323 |
| 1999 | 59.51 | 74.98 | 134.49 | 27 | 23.45 | 50.45 | 2.66581 |
| 2000 | 60.06 | 75.86 | 135.92 | 27.35 | 23.81 | 51.16 | 2.65676 |
| 2001 | 60.65 | 76.76 | 137.41 | 27.7 | 24.15 | 51.85 | 2.65014 |
| 2002 | 61.22 | 77.68 | 138.9 | 28.05 | 24.53 | 52.58 | 2.64169 |
| 2003 | 61.83 | 78.6 | 140.43 | 28.42 | 24.89 | 53.31 | 2.63421 |
| 2004 | 62.4 | 79.55 | 141.95 | 28.79 | 25.26 | 54.05 | 2.62627 |
| 2005 | 62.99 | 80.51 | 143.5 | 29.16 | 25.64 | 54.8 | 2.61861 |
| 2006 | 63.59 | 81.47 | 145.06 | 29.54 | 26.02 | 55.56 | 2.61087 |
| 2007 | 64.19 | 82.45 | 146.64 | 29.91 | 26.43 | 56.34 | 2.60277 |
| 2008 | 64.8 | 83.42 | 148.22 | 30.31 | 26.83 | 57.14 | 2.59398 |
| 2009 | 65.4 | 84.43 | 149.83 | 30.7 | 27.23 | 57.93 | 2.5864 |
| 2010 | 66.02 | 85.46 | 151.48 | 31.09 | 27.65 | 58.74 | 2.57882 |
| 2011 | 66.63 | 86.46 | 153.09 | 31.51 | 28.05 | 59.56 | 2.57035 |
| 2012 | 67.25 | 87.51 | 154.76 | 31.92 | 28.46 | 60.38 | 2.5631 |
| 2013 | 67.86 | 88.55 | 156.41 | 32.32 | 28.88 | 61.2 | 2.55572 |
| 2014 | 68.5 | 89.62 | 158.12 | 32.75 | 29.3 | 62.05 | 2.54827 |
| Final | 69.12 | 90.7 | 159.82 | 33.17 | 29.73 | 62.9 | 2.54086 |

SW=softwood HW=hardwood MMCF=Million cubic feet

# Appendix E

## Stella© Model Net Growth and Drain runs by species

**Total Growth by species at 20% reduction in**

| | BF MMCF | RS MMCF | WP MMCF | H MMCF | OS MMCF | SM MMCF | RM MMCF | YB MMCF | PB MMCF | B MMCF | WA MMCF | A MMCF | RO MMCF | OH MMCF | TOT SW MMCF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1983 | 15.52 | 10.21 | 33.42 | 13.09 | 2.83 | 10.19 | 23.45 | 7.07 | 7.21 | 6.63 | 6.11 | 5.49 | 16.96 | 3.43 | 75.07 |
| 1984 | 15.72 | 10.25 | 33.73 | 13.12 | 2.81 | 10.29 | 23.82 | 7.12 | 7.24 | 6.66 | 6.23 | 5.53 | 17.2 | 3.3 | 75.63 |
| 1985 | 15.92 | 10.3 | 34.04 | 13.16 | 2.8 | 10.4 | 24.2 | 7.16 | 7.27 | 6.69 | 6.34 | 5.58 | 17.44 | 3.17 | 76.22 |
| 1986 | 16.12 | 10.34 | 34.36 | 13.19 | 2.78 | 10.5 | 24.58 | 7.21 | 7.3 | 6.73 | 6.46 | 5.62 | 17.69 | 3.04 | 76.79 |
| 1987 | 16.32 | 10.38 | 34.68 | 13.22 | 2.76 | 10.61 | 24.97 | 7.25 | 7.33 | 6.76 | 6.58 | 5.66 | 17.94 | 2.92 | 77.36 |
| 1988 | 16.53 | 10.43 | 35 | 13.26 | 2.74 | 10.72 | 25.36 | 7.3 | 7.37 | 6.79 | 6.7 | 5.71 | 18.19 | 2.8 | 77.96 |
| 1989 | 16.74 | 10.47 | 35.33 | 13.29 | 2.73 | 10.83 | 25.76 | 7.34 | 7.4 | 6.82 | 6.83 | 5.75 | 18.44 | 2.68 | 78.56 |
| 1990 | 16.95 | 10.52 | 35.67 | 13.32 | 2.71 | 10.94 | 26.16 | 7.39 | 7.43 | 6.86 | 6.95 | 5.8 | 18.7 | 2.57 | 79.17 |
| 1991 | 17.16 | 10.56 | 36.01 | 13.36 | 2.69 | 11.05 | 26.57 | 7.43 | 7.46 | 6.89 | 7.08 | 5.84 | 18.96 | 2.46 | 79.78 |
| 1992 | 17.37 | 10.61 | 36.35 | 13.39 | 2.67 | 11.16 | 26.99 | 7.48 | 7.49 | 6.92 | 7.21 | 5.89 | 19.22 | 2.35 | 80.39 |
| 1993 | 17.59 | 10.65 | 36.7 | 13.42 | 2.65 | 11.27 | 27.42 | 7.53 | 7.53 | 6.96 | 7.34 | 5.94 | 19.49 | 2.25 | 81.01 |
| 1994 | 17.8 | 10.7 | 37.05 | 13.45 | 2.63 | 11.39 | 27.85 | 7.57 | 7.56 | 6.99 | 7.48 | 5.98 | 19.75 | 2.15 | 81.63 |
| 1995 | 18.02 | 10.75 | 37.41 | 13.48 | 2.61 | 11.5 | 28.28 | 7.62 | 7.59 | 7.03 | 7.61 | 6.03 | 20.03 | 2.05 | 82.27 |
| 1996 | 18.24 | 10.79 | 37.78 | 13.51 | 2.59 | 11.62 | 28.73 | 7.66 | 7.62 | 7.06 | 7.75 | 6.08 | 20.3 | 1.96 | 82.91 |
| 1997 | 18.47 | 10.84 | 38.15 | 13.54 | 2.57 | 11.74 | 29.18 | 7.71 | 7.66 | 7.09 | 7.9 | 6.13 | 20.58 | 1.86 | 83.57 |
| 1998 | 18.69 | 10.89 | 38.52 | 13.57 | 2.55 | 11.86 | 29.63 | 7.76 | 7.69 | 7.13 | 8.04 | 6.17 | 20.86 | 1.77 | 84.22 |
| 1999 | 18.93 | 10.95 | 38.94 | 13.62 | 2.53 | 11.98 | 30.1 | 7.81 | 7.72 | 7.16 | 8.19 | 6.23 | 21.16 | 1.73 | 84.97 |
| 2000 | 19.19 | 11.02 | 39.39 | 13.69 | 2.52 | 12.1 | 30.58 | 7.86 | 7.76 | 7.2 | 8.34 | 6.28 | 21.47 | 1.73 | 85.81 |
| 2001 | 19.47 | 11.11 | 39.88 | 13.78 | 2.51 | 12.23 | 31.06 | 7.91 | 7.79 | 7.23 | 8.49 | 6.33 | 21.8 | 1.74 | 86.75 |
| 2002 | 19.76 | 11.21 | 40.4 | 13.9 | 2.5 | 12.35 | 31.56 | 7.96 | 7.83 | 7.27 | 8.65 | 6.38 | 22.14 | 1.75 | 87.77 |
| 2003 | 20.06 | 11.31 | 40.94 | 14.01 | 2.49 | 12.48 | 32.06 | 8.01 | 7.86 | 7.31 | 8.81 | 6.44 | 22.48 | 1.76 | 88.81 |
| 2004 | 20.36 | 11.42 | 41.48 | 14.12 | 2.48 | 12.61 | 32.57 | 8.06 | 7.9 | 7.34 | 8.97 | 6.5 | 22.83 | 1.77 | 89.86 |
| 2005 | 20.67 | 11.52 | 42.04 | 14.24 | 2.48 | 12.74 | 33.09 | 8.12 | 7.94 | 7.38 | 9.14 | 6.55 | 23.19 | 1.78 | 90.95 |
| 2006 | 20.98 | 11.63 | 42.6 | 14.36 | 2.47 | 12.87 | 33.61 | 8.17 | 7.97 | 7.42 | 9.31 | 6.61 | 23.55 | 1.79 | 92.04 |
| 2007 | 21.29 | 11.73 | 43.17 | 14.47 | 2.46 | 13.01 | 34.15 | 8.22 | 8.01 | 7.46 | 9.48 | 6.67 | 23.91 | 1.8 | 93.12 |
| 2008 | 21.6 | 11.84 | 43.74 | 14.59 | 2.45 | 13.14 | 34.69 | 8.28 | 8.04 | 7.49 | 9.65 | 6.72 | 24.28 | 1.81 | 94.22 |
| 2009 | 21.92 | 11.95 | 44.33 | 14.71 | 2.44 | 13.28 | 35.24 | 8.33 | 8.08 | 7.53 | 9.83 | 6.78 | 24.66 | 1.82 | 95.35 |
| 2010 | 22.25 | 12.06 | 44.93 | 14.84 | 2.43 | 13.41 | 35.8 | 8.39 | 8.12 | 7.57 | 10.01 | 6.84 | 25.04 | 1.83 | 96.51 |
| 2011 | 22.57 | 12.17 | 45.53 | 14.96 | 2.42 | 13.55 | 36.37 | 8.44 | 8.15 | 7.61 | 10.19 | 6.9 | 25.42 | 1.85 | 97.65 |
| 2012 | 22.9 | 12.29 | 46.14 | 15.08 | 2.41 | 13.69 | 36.94 | 8.49 | 8.19 | 7.64 | 10.38 | 6.96 | 25.81 | 1.86 | 98.82 |
| 2013 | 23.24 | 12.4 | 46.77 | 15.21 | 2.4 | 13.83 | 37.53 | 8.55 | 8.23 | 7.68 | 10.57 | 7.02 | 26.21 | 1.87 | 100.02 |
| 2014 | 23.58 | 12.52 | 47.4 | 15.34 | 2.39 | 13.98 | 38.12 | 8.6 | 8.26 | 7.72 | 10.76 | 7.08 | 26.61 | 1.88 | 101.23 |
| Final | 23.92 | 12.64 | 48.04 | 15.46 | 2.38 | 14.12 | 38.72 | 8.66 | 8.3 | 7.76 | 10.95 | 7.14 | 27.02 | 1.89 | 102.44 |

**Total Drain by species at 20% reduction in chip markets over 5 years (80% availability)**

| | BF MMCF | RS MMCF | WP MMCF | H MMCF | OS MMCF | SM MMCF | RM MMCF | YB MMCF | PB MMCF | B MMCF | WA MMCF | A MMCF | RO MMCF | OH MMCF | TOT SW MMCF | TOT HW MMCF | GRAND TOTAL MMCF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1983 | 5.78 | 5.74 | 14.46 | 8.5 | 2.98 | 1.67 | 5.67 | 2.85 | 2.48 | 2.66 | 0.77 | 0.78 | 5.35 | 10.19 | 37.46 | 32.42 | 69.88 |
| 1984 | 5.86 | 5.76 | 14.6 | 8.54 | 2.98 | 1.69 | 5.78 | 2.87 | 2.5 | 2.68 | 0.8 | 0.79 | 5.47 | 9.89 | 37.74 | 32.47 | 70.21 |
| 1985 | 5.95 | 5.78 | 14.75 | 8.58 | 2.98 | 1.72 | 5.88 | 2.89 | 2.52 | 2.7 | 0.82 | 0.8 | 5.6 | 9.6 | 38.04 | 32.53 | 70.57 |
| 1986 | 6.04 | 5.81 | 14.89 | 8.62 | 2.98 | 1.75 | 5.99 | 2.92 | 2.55 | 2.72 | 0.84 | 0.81 | 5.73 | 9.32 | 38.34 | 32.63 | 70.97 |
| 1987 | 6.14 | 5.83 | 15.04 | 8.66 | 2.98 | 1.77 | 6.09 | 2.94 | 2.57 | 2.74 | 0.86 | 0.82 | 5.86 | 9.05 | 38.65 | 32.7 | 71.35 |
| 1988 | 6.23 | 5.85 | 15.19 | 8.7 | 2.98 | 1.8 | 6.2 | 2.96 | 2.6 | 2.77 | 0.88 | 0.83 | 5.99 | 8.78 | 38.95 | 32.81 | 71.76 |
| 1989 | 6.32 | 5.87 | 15.34 | 8.74 | 2.98 | 1.83 | 6.31 | 2.99 | 2.62 | 2.79 | 0.9 | 0.84 | 6.12 | 8.53 | 39.25 | 32.93 | 72.18 |
| 1990 | 6.42 | 5.89 | 15.49 | 8.78 | 2.99 | 1.86 | 6.42 | 3.01 | 2.64 | 2.81 | 0.93 | 0.85 | 6.26 | 8.28 | 39.57 | 33.06 | 72.63 |
| 1991 | 6.52 | 5.91 | 15.65 | 8.82 | 2.99 | 1.88 | 6.54 | 3.04 | 2.67 | 2.83 | 0.95 | 0.86 | 6.39 | 8.04 | 39.89 | 33.2 | 73.09 |
| 1992 | 6.62 | 5.93 | 15.81 | 8.86 | 2.99 | 1.91 | 6.65 | 3.06 | 2.69 | 2.85 | 0.98 | 0.87 | 6.52 | 7.81 | 40.21 | 33.34 | 73.55 |
| 1993 | 6.72 | 5.96 | 15.97 | 8.9 | 2.99 | 1.94 | 6.77 | 3.09 | 2.72 | 2.88 | 1 | 0.88 | 6.66 | 7.58 | 40.54 | 33.52 | 74.06 |
| 1994 | 6.82 | 5.98 | 16.14 | 8.95 | 2.99 | 1.97 | 6.89 | 3.11 | 2.74 | 2.9 | 1.03 | 0.89 | 6.8 | 7.36 | 40.88 | 33.69 | 74.57 |
| 1995 | 6.92 | 6 | 16.31 | 8.99 | 2.99 | 2 | 7.01 | 3.13 | 2.76 | 2.92 | 1.05 | 0.9 | 6.93 | 7.15 | 41.21 | 33.85 | 75.06 |
| 1996 | 7.02 | 6.03 | 16.48 | 9.03 | 2.99 | 2.03 | 7.13 | 3.16 | 2.79 | 2.94 | 1.08 | 0.91 | 7.07 | 6.95 | 41.55 | 34.06 | 75.61 |
| 1997 | 7.13 | 6.05 | 16.65 | 9.07 | 2.99 | 2.06 | 7.25 | 3.18 | 2.81 | 2.96 | 1.1 | 0.93 | 7.21 | 6.75 | 41.89 | 34.25 | 76.14 |
| 1998 | 6.84 | 5.53 | 15.73 | 8.52 | 2.85 | 2.07 | 7.3 | 3.17 | 2.79 | 2.97 | 1.11 | 0.9 | 7.07 | 4.08 | 39.47 | 31.46 | 70.93 |
| 1999 | 6.55 | 5.02 | 14.81 | 7.96 | 2.71 | 2.08 | 7.34 | 3.16 | 2.78 | 2.97 | 1.12 | 0.87 | 6.94 | 1.41 | 37.05 | 28.67 | 65.72 |
| 2000 | 6.26 | 4.5 | 13.89 | 7.41 | 2.57 | 2.09 | 7.39 | 3.14 | 2.76 | 2.97 | 1.13 | 0.84 | 6.8 | 1.09 | 34.63 | 28.21 | 62.84 |
| 2001 | 5.97 | 3.99 | 12.98 | 6.86 | 2.43 | 2.11 | 7.45 | 3.13 | 2.75 | 2.97 | 1.14 | 0.81 | 6.66 | 1.09 | 32.23 | 28.11 | 60.34 |
| 2002 | 6.09 | 4.01 | 13.17 | 6.91 | 2.44 | 2.14 | 7.58 | 3.15 | 2.77 | 3 | 1.17 | 0.83 | 6.81 | 1.09 | 32.62 | 28.54 | 61.16 |
| 2003 | 6.2 | 4.04 | 13.37 | 6.97 | 2.44 | 2.17 | 7.72 | 3.18 | 2.79 | 3.02 | 1.2 | 0.84 | 6.96 | 1.09 | 33.02 | 28.97 | 61.99 |
| 2004 | 6.32 | 4.07 | 13.57 | 7.02 | 2.44 | 2.2 | 7.85 | 3.21 | 2.82 | 3.04 | 1.23 | 0.85 | 7.1 | 1.09 | 33.42 | 29.39 | 62.81 |
| 2005 | 6.44 | 4.1 | 13.77 | 7.07 | 2.44 | 2.24 | 7.99 | 3.23 | 2.84 | 3.07 | 1.26 | 0.86 | 7.25 | 1.09 | 33.82 | 29.83 | 63.65 |
| 2006 | 6.57 | 4.12 | 13.98 | 7.13 | 2.44 | 2.27 | 8.13 | 3.26 | 2.87 | 3.09 | 1.29 | 0.88 | 7.4 | 1.08 | 34.24 | 30.27 | 64.51 |
| 2007 | 6.69 | 4.15 | 14.18 | 7.19 | 2.44 | 2.31 | 8.28 | 3.29 | 2.89 | 3.11 | 1.32 | 0.89 | 7.56 | 1.08 | 34.65 | 30.73 | 65.38 |
| 2008 | 6.81 | 4.18 | 14.4 | 7.24 | 2.45 | 2.34 | 8.42 | 3.32 | 2.92 | 3.14 | 1.36 | 0.9 | 7.71 | 1.08 | 35.08 | 31.19 | 66.27 |
| 2009 | 6.94 | 4.21 | 14.61 | 7.3 | 2.45 | 2.38 | 8.57 | 3.34 | 2.94 | 3.16 | 1.39 | 0.92 | 7.86 | 1.07 | 35.51 | 31.63 | 67.14 |
| 2010 | 7.07 | 4.24 | 14.83 | 7.36 | 2.45 | 2.41 | 8.72 | 3.37 | 2.96 | 3.18 | 1.42 | 0.93 | 8.02 | 1.07 | 35.95 | 32.08 | 68.03 |
| 2011 | 7.2 | 4.27 | 15.06 | 7.41 | 2.45 | 2.45 | 8.87 | 3.4 | 2.99 | 3.21 | 1.46 | 0.94 | 8.18 | 1.07 | 36.39 | 32.57 | 68.96 |
| 2012 | 7.34 | 4.3 | 15.28 | 7.47 | 2.45 | 2.48 | 9.03 | 3.43 | 3.01 | 3.23 | 1.5 | 0.96 | 8.33 | 1.06 | 36.84 | 33.03 | 69.87 |
| 2013 | 7.47 | 4.33 | 15.52 | 7.53 | 2.46 | 2.52 | 9.18 | 3.45 | 3.04 | 3.26 | 1.53 | 0.97 | 8.49 | 1.06 | 37.31 | 33.5 | 70.81 |
| 2014 | 7.61 | 4.36 | 15.75 | 7.59 | 2.46 | 2.56 | 9.34 | 3.48 | 3.06 | 3.28 | 1.57 | 0.98 | 8.65 | 1.05 | 37.77 | 33.97 | 71.74 |
| Final | 7.75 | 4.39 | 15.99 | 7.65 | 2.46 | 2.6 | 9.5 | 3.51 | 3.09 | 3.3 | 1.61 | 1 | 8.82 | 1.05 | 38.24 | 34.48 | 72.72 |

**Total Growth by species at 20% reduction in chip markets over 5 years (60% availability)**

| | BF MMCF | RS MMCF | WP MMCF | H MMCF | OS MMCF | SM MMCF | RM MMCF | YB MMCF | PB MMCF | B MMCF | WA MMCF | A MMCF | RO MMCF | OH MMCF | TOT SW MMCF | TOT HW MMCF | GRAND TOTAL MMCF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1983 | 11.64 | 7.66 | 25.07 | 9.82 | 2.12 | 7.64 | 17.59 | 5.3 | 5.41 | 4.97 | 4.58 | 4.12 | 12.72 | 2.58 | 56.31 | 64.91 | 121.22 |
| 1984 | 11.74 | 7.66 | 25.21 | 9.79 | 2.09 | 7.72 | 17.85 | 5.33 | 5.43 | 4.99 | 4.66 | 4.15 | 12.88 | 2.43 | 56.49 | 65.44 | 121.93 |
| 1985 | 11.85 | 7.66 | 25.35 | 9.76 | 2.06 | 7.79 | 18.13 | 5.36 | 5.45 | 5.01 | 4.75 | 4.18 | 13.03 | 2.29 | 56.68 | 65.99 | 122.67 |
| 1986 | 11.95 | 7.66 | 25.49 | 9.73 | 2.03 | 7.87 | 18.4 | 5.39 | 5.47 | 5.04 | 4.83 | 4.2 | 13.19 | 2.16 | 56.86 | 66.55 | 123.41 |
| 1987 | 12.05 | 7.67 | 25.64 | 9.71 | 2 | 7.95 | 18.68 | 5.42 | 5.49 | 5.06 | 4.91 | 4.23 | 13.34 | 2.02 | 57.07 | 67.1 | 124.17 |
| 1988 | 12.15 | 7.67 | 25.78 | 9.67 | 1.97 | 8.03 | 18.96 | 5.45 | 5.51 | 5.08 | 5 | 4.26 | 13.5 | 1.9 | 57.24 | 67.69 | 124.93 |
| 1989 | 12.25 | 7.67 | 25.93 | 9.64 | 1.93 | 8.11 | 19.25 | 5.47 | 5.53 | 5.1 | 5.09 | 4.29 | 13.66 | 1.77 | 57.42 | 68.27 | 125.69 |
| 1990 | 12.34 | 7.67 | 26.08 | 9.61 | 1.9 | 8.19 | 19.54 | 5.5 | 5.55 | 5.13 | 5.18 | 4.32 | 13.82 | 1.65 | 57.6 | 68.88 | 126.48 |
| 1991 | 12.44 | 7.67 | 26.23 | 9.57 | 1.87 | 8.27 | 19.84 | 5.53 | 5.57 | 5.15 | 5.27 | 4.35 | 13.99 | 1.53 | 57.78 | 69.5 | 127.28 |
| 1992 | 12.54 | 7.67 | 26.37 | 9.53 | 1.83 | 8.35 | 20.14 | 5.56 | 5.6 | 5.17 | 5.36 | 4.38 | 14.15 | 1.41 | 57.94 | 70.12 | 128.06 |
| 1993 | 12.64 | 7.67 | 26.52 | 9.5 | 1.8 | 8.44 | 20.44 | 5.59 | 5.62 | 5.19 | 5.45 | 4.42 | 14.31 | 1.3 | 58.13 | 70.76 | 128.89 |
| 1994 | 12.73 | 7.67 | 26.67 | 9.46 | 1.76 | 8.52 | 20.75 | 5.62 | 5.64 | 5.22 | 5.54 | 4.45 | 14.48 | 1.19 | 58.29 | 71.41 | 129.7 |
| 1995 | 12.83 | 7.67 | 26.83 | 9.41 | 1.72 | 8.61 | 21.06 | 5.65 | 5.66 | 5.24 | 5.64 | 4.48 | 14.65 | 1.08 | 58.46 | 72.07 | 130.53 |
| 1996 | 12.92 | 7.67 | 26.98 | 9.37 | 1.69 | 8.69 | 21.38 | 5.67 | 5.68 | 5.26 | 5.73 | 4.51 | 14.82 | 0.97 | 58.63 | 72.71 | 131.34 |
| 1997 | 13.01 | 7.66 | 27.13 | 9.32 | 1.65 | 8.78 | 21.7 | 5.7 | 5.7 | 5.28 | 5.83 | 4.54 | 14.98 | 0.87 | 58.77 | 73.38 | 132.15 |
| 1998 | 13.1 | 7.66 | 27.28 | 9.28 | 1.61 | 8.87 | 22.03 | 5.73 | 5.72 | 5.31 | 5.93 | 4.57 | 15.16 | 0.77 | 58.93 | 74.09 | 133.02 |
| 1999 | 13.21 | 7.67 | 27.47 | 9.25 | 1.57 | 8.96 | 22.36 | 5.76 | 5.75 | 5.33 | 6.03 | 4.61 | 15.34 | 0.72 | 59.17 | 74.86 | 134.03 |
| 2000 | 13.33 | 7.69 | 27.69 | 9.24 | 1.54 | 9.05 | 22.7 | 5.79 | 5.77 | 5.35 | 6.14 | 4.64 | 15.53 | 0.71 | 59.49 | 75.68 | 135.17 |
| 2001 | 13.46 | 7.73 | 27.94 | 9.25 | 1.51 | 9.14 | 23.05 | 5.83 | 5.79 | 5.38 | 6.25 | 4.68 | 15.74 | 0.71 | 59.89 | 76.57 | 136.46 |
| 2002 | 13.6 | 7.78 | 28.22 | 9.28 | 1.48 | 9.23 | 23.4 | 5.86 | 5.82 | 5.4 | 6.36 | 4.71 | 15.96 | 0.71 | 60.36 | 77.45 | 137.81 |
| 2003 | 13.75 | 7.82 | 28.51 | 9.31 | 1.45 | 9.32 | 23.76 | 5.89 | 5.84 | 5.43 | 6.47 | 4.75 | 16.19 | 0.71 | 60.84 | 78.36 | 139.2 |
| 2004 | 13.9 | 7.87 | 28.8 | 9.34 | 1.43 | 9.42 | 24.13 | 5.92 | 5.86 | 5.45 | 6.58 | 4.79 | 16.41 | 0.71 | 61.34 | 79.27 | 140.61 |
| 2005 | 14.04 | 7.92 | 29.1 | 9.37 | 1.4 | 9.51 | 24.5 | 5.96 | 5.89 | 5.48 | 6.69 | 4.83 | 16.64 | 0.7 | 61.83 | 80.2 | 142.03 |
| 2006 | 14.19 | 7.97 | 29.39 | 9.39 | 1.37 | 9.61 | 24.88 | 5.99 | 5.91 | 5.5 | 6.81 | 4.87 | 16.87 | 0.7 | 62.31 | 81.14 | 143.45 |
| 2007 | 14.34 | 8.02 | 29.69 | 9.42 | 1.34 | 9.71 | 25.26 | 6.03 | 5.94 | 5.53 | 6.93 | 4.91 | 17.1 | 0.7 | 62.81 | 82.11 | 144.92 |
| 2008 | 14.48 | 8.07 | 30 | 9.45 | 1.31 | 9.81 | 25.65 | 6.06 | 5.96 | 5.55 | 7.05 | 4.95 | 17.34 | 0.7 | 63.31 | 83.07 | 146.38 |
| 2009 | 14.63 | 8.12 | 30.3 | 9.48 | 1.28 | 9.91 | 26.04 | 6.09 | 5.99 | 5.58 | 7.17 | 4.99 | 17.58 | 0.7 | 63.81 | 84.05 | 147.86 |
| 2010 | 14.77 | 8.17 | 30.61 | 9.5 | 1.24 | 10.01 | 26.44 | 6.13 | 6.01 | 5.61 | 7.29 | 5.03 | 17.82 | 0.7 | 64.29 | 85.04 | 149.33 |
| 2011 | 14.92 | 8.22 | 30.92 | 9.53 | 1.21 | 10.11 | 26.85 | 6.16 | 6.04 | 5.63 | 7.42 | 5.07 | 18.06 | 0.7 | 64.8 | 86.04 | 150.84 |
| 2012 | 15.06 | 8.27 | 31.23 | 9.56 | 1.18 | 10.21 | 27.26 | 6.2 | 6.06 | 5.66 | 7.54 | 5.11 | 18.31 | 0.7 | 65.3 | 87.05 | 152.35 |
| 2013 | 15.2 | 8.32 | 31.55 | 9.58 | 1.14 | 10.32 | 27.68 | 6.23 | 6.09 | 5.68 | 7.67 | 5.15 | 18.55 | 0.7 | 65.79 | 88.07 | 153.86 |
| 2014 | 15.34 | 8.37 | 31.86 | 9.61 | 1.11 | 10.42 | 28.1 | 6.26 | 6.11 | 5.71 | 7.8 | 5.19 | 18.81 | 0.7 | 66.29 | 89.1 | 155.39 |
| Final | 15.48 | 8.42 | 32.18 | 9.63 | 1.07 | 10.53 | 28.53 | 6.3 | 6.14 | 5.73 | 7.93 | 5.23 | 19.06 | 0.7 | 66.78 | 90.15 | 156.93 |

**Total Drain by species at 20% reduction in chip markets over 5 years (60% availability)**

| | BF MMCF | RS MMCF | WP MMCF | H MMCF | OS MMCF | SM MMCF | RM MMCF | YB MMCF | PB MMCF | B MMCF | WA MMCF | A MMCF | RO MMCF | OH MMCF | TOT SW MMCF | TOT HW MMCF | GRAND TOTAL MMCF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1983 | 5.68 | 5.62 | 14.03 | 7.97 | 2.94 | 1.33 | 4.75 | 2.46 | 2.1 | 2.12 | 0.76 | 0.72 | 5.35 | 10.14 | 36.24 | 29.73 | 65.97 |
| 1984 | 5.76 | 5.64 | 14.16 | 8 | 2.94 | 1.35 | 4.83 | 2.48 | 2.12 | 2.14 | 0.78 | 0.73 | 5.47 | 9.84 | 36.5 | 29.74 | 66.24 |
| 1985 | 5.85 | 5.66 | 14.29 | 8.03 | 2.94 | 1.37 | 4.92 | 2.5 | 2.14 | 2.15 | 0.8 | 0.74 | 5.6 | 9.55 | 36.77 | 29.77 | 66.54 |
| 1986 | 5.94 | 5.68 | 14.42 | 8.06 | 2.94 | 1.39 | 5 | 2.51 | 2.16 | 2.17 | 0.82 | 0.75 | 5.73 | 9.27 | 37.04 | 29.8 | 66.84 |
| 1987 | 6.03 | 5.7 | 14.56 | 8.09 | 2.94 | 1.42 | 5.09 | 2.53 | 2.18 | 2.19 | 0.84 | 0.76 | 5.86 | 8.99 | 37.32 | 29.86 | 67.18 |
| 1988 | 6.12 | 5.72 | 14.7 | 8.12 | 2.94 | 1.44 | 5.18 | 2.55 | 2.2 | 2.2 | 0.86 | 0.77 | 5.99 | 8.73 | 37.6 | 29.92 | 67.52 |
| 1989 | 6.21 | 5.74 | 14.84 | 8.15 | 2.94 | 1.46 | 5.27 | 2.57 | 2.22 | 2.22 | 0.89 | 0.78 | 6.12 | 8.47 | 37.88 | 30 | 67.88 |
| 1990 | 6.3 | 5.76 | 14.98 | 8.17 | 2.94 | 1.48 | 5.36 | 2.59 | 2.24 | 2.24 | 0.91 | 0.79 | 6.26 | 8.22 | 38.15 | 30.09 | 68.24 |
| 1991 | 6.4 | 5.78 | 15.12 | 8.2 | 2.94 | 1.5 | 5.45 | 2.61 | 2.26 | 2.25 | 0.93 | 0.8 | 6.39 | 7.98 | 38.44 | 30.17 | 68.61 |
| 1992 | 6.49 | 5.8 | 15.27 | 8.23 | 2.94 | 1.53 | 5.55 | 2.63 | 2.28 | 2.27 | 0.96 | 0.81 | 6.52 | 7.75 | 38.73 | 30.3 | 69.03 |
| 1993 | 6.59 | 5.82 | 15.42 | 8.26 | 2.94 | 1.55 | 5.64 | 2.65 | 2.3 | 2.29 | 0.98 | 0.82 | 6.66 | 7.52 | 39.03 | 30.41 | 69.44 |
| 1994 | 6.69 | 5.84 | 15.57 | 8.29 | 2.95 | 1.57 | 5.74 | 2.67 | 2.32 | 2.3 | 1.01 | 0.83 | 6.8 | 7.3 | 39.34 | 30.54 | 69.88 |
| 1995 | 6.79 | 5.86 | 15.72 | 8.32 | 2.95 | 1.6 | 5.83 | 2.69 | 2.34 | 2.32 | 1.03 | 0.84 | 6.93 | 7.09 | 39.64 | 30.67 | 70.31 |
| 1996 | 6.89 | 5.88 | 15.88 | 8.35 | 2.95 | 1.62 | 5.93 | 2.71 | 2.36 | 2.34 | 1.06 | 0.85 | 7.07 | 6.89 | 39.95 | 30.83 | 70.78 |
| 1997 | 6.99 | 5.9 | 16.04 | 8.37 | 2.95 | 1.64 | 6.03 | 2.73 | 2.38 | 2.35 | 1.08 | 0.86 | 7.21 | 6.69 | 40.25 | 30.97 | 71.22 |
| 1998 | 6.7 | 5.38 | 15.1 | 7.8 | 2.81 | 1.65 | 6.05 | 2.71 | 2.36 | 2.35 | 1.09 | 0.83 | 7.07 | 4.01 | 37.79 | 28.12 | 65.91 |
| 1999 | 6.4 | 4.86 | 14.16 | 7.23 | 2.67 | 1.65 | 6.08 | 2.69 | 2.34 | 2.35 | 1.1 | 0.8 | 6.94 | 1.35 | 35.32 | 25.3 | 60.62 |
| 2000 | 6.11 | 4.34 | 13.23 | 6.67 | 2.53 | 1.66 | 6.1 | 2.67 | 2.32 | 2.35 | 1.11 | 0.77 | 6.8 | 1.03 | 32.88 | 24.81 | 57.69 |
| 2001 | 5.82 | 3.83 | 12.31 | 6.1 | 2.39 | 1.66 | 6.13 | 2.65 | 2.3 | 2.34 | 1.11 | 0.74 | 6.66 | 1.03 | 30.45 | 24.62 | 55.07 |
| 2002 | 5.93 | 3.85 | 12.48 | 6.14 | 2.39 | 1.69 | 6.24 | 2.67 | 2.32 | 2.36 | 1.14 | 0.75 | 6.81 | 1.02 | 30.79 | 25 | 55.79 |
| 2003 | 6.04 | 3.87 | 12.66 | 6.18 | 2.39 | 1.71 | 6.35 | 2.7 | 2.34 | 2.38 | 1.17 | 0.76 | 6.96 | 1.02 | 31.14 | 25.39 | 56.53 |
| 2004 | 6.16 | 3.9 | 12.84 | 6.22 | 2.39 | 1.74 | 6.46 | 2.72 | 2.36 | 2.4 | 1.2 | 0.78 | 7.1 | 1.02 | 31.51 | 25.78 | 57.29 |
| 2005 | 6.27 | 3.92 | 13.03 | 6.25 | 2.39 | 1.77 | 6.57 | 2.74 | 2.38 | 2.41 | 1.23 | 0.79 | 7.25 | 1.01 | 31.86 | 26.15 | 58.01 |
| 2006 | 6.39 | 3.95 | 13.21 | 6.29 | 2.39 | 1.79 | 6.68 | 2.76 | 2.4 | 2.43 | 1.27 | 0.8 | 7.4 | 1.01 | 32.23 | 26.54 | 58.77 |
| 2007 | 6.51 | 3.97 | 13.4 | 6.33 | 2.39 | 1.82 | 6.8 | 2.78 | 2.42 | 2.45 | 1.3 | 0.81 | 7.56 | 1.01 | 32.6 | 26.95 | 59.55 |
| 2008 | 6.63 | 4 | 13.6 | 6.37 | 2.4 | 1.85 | 6.92 | 2.8 | 2.44 | 2.47 | 1.33 | 0.82 | 7.71 | 1 | 33 | 27.34 | 60.34 |
| 2009 | 6.76 | 4.03 | 13.79 | 6.41 | 2.4 | 1.88 | 7.04 | 2.83 | 2.46 | 2.49 | 1.36 | 0.84 | 7.86 | 1 | 33.39 | 27.76 | 61.15 |
| 2010 | 6.88 | 4.05 | 13.99 | 6.45 | 2.4 | 1.91 | 7.16 | 2.85 | 2.48 | 2.5 | 1.4 | 0.85 | 8.02 | 0.99 | 33.77 | 28.16 | 61.93 |
| 2011 | 7.01 | 4.08 | 14.2 | 6.49 | 2.4 | 1.93 | 7.28 | 2.87 | 2.5 | 2.52 | 1.43 | 0.86 | 8.18 | 0.99 | 34.18 | 28.56 | 62.74 |
| 2012 | 7.14 | 4.1 | 14.4 | 6.53 | 2.4 | 1.96 | 7.4 | 2.89 | 2.52 | 2.54 | 1.47 | 0.87 | 8.33 | 0.98 | 34.57 | 28.96 | 63.53 |
| 2013 | 7.27 | 4.13 | 14.61 | 6.57 | 2.4 | 1.99 | 7.53 | 2.91 | 2.54 | 2.56 | 1.5 | 0.88 | 8.49 | 0.98 | 34.98 | 29.38 | 64.36 |
| 2014 | 7.4 | 4.16 | 14.83 | 6.61 | 2.4 | 2.02 | 7.66 | 2.94 | 2.56 | 2.58 | 1.54 | 0.9 | 8.65 | 0.97 | 35.4 | 29.82 | 65.22 |
| Final | 7.53 | 4.19 | 15.04 | 6.65 | 2.4 | 2.05 | 7.78 | 2.96 | 2.58 | 2.59 | 1.58 | 0.91 | 8.82 | 0.97 | 35.81 | 30.24 | 66.05 |

**Total Growth by species at 100% reduction in chip markets over 1 year (80% availability)**

| | BF MMCF | RS MMCF | WP MMCF | H MMCF | OS MMCF | SM MMCF | RM MMCF | YB MMCF | PB MMCF | B MMCF | WA MMCF | A MMCF | RO MMCF | OH MMCF | TOT SW MMCF | TOT HW MMCF | GRAND TOTAL MMCF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1983 | 15.52 | 10.21 | 33.42 | 13.09 | 2.83 | 10.19 | 23.45 | 7.07 | 7.21 | 6.63 | 6.11 | 5.49 | 16.96 | 3.43 | 75.07 | 86.54 | 161.61 |
| 1984 | 15.72 | 10.25 | 33.73 | 13.12 | 2.81 | 10.29 | 23.82 | 7.12 | 7.24 | 6.66 | 6.23 | 5.53 | 17.2 | 3.3 | 75.63 | 87.39 | 163.02 |
| 1985 | 15.92 | 10.3 | 34.04 | 13.16 | 2.8 | 10.4 | 24.2 | 7.16 | 7.27 | 6.69 | 6.34 | 5.58 | 17.44 | 3.17 | 76.22 | 88.25 | 164.47 |
| 1986 | 16.12 | 10.34 | 34.36 | 13.19 | 2.78 | 10.5 | 24.58 | 7.21 | 7.3 | 6.73 | 6.46 | 5.62 | 17.69 | 3.04 | 76.79 | 89.13 | 165.92 |
| 1987 | 16.32 | 10.38 | 34.68 | 13.22 | 2.76 | 10.61 | 24.97 | 7.25 | 7.33 | 6.76 | 6.58 | 5.66 | 17.94 | 2.92 | 77.36 | 90.02 | 167.38 |
| 1988 | 16.53 | 10.43 | 35 | 13.26 | 2.74 | 10.72 | 25.36 | 7.3 | 7.37 | 6.79 | 6.7 | 5.71 | 18.19 | 2.8 | 77.96 | 90.94 | 168.9 |
| 1989 | 16.74 | 10.47 | 35.33 | 13.29 | 2.73 | 10.83 | 25.76 | 7.34 | 7.4 | 6.82 | 6.83 | 5.75 | 18.44 | 2.68 | 78.56 | 91.85 | 170.41 |
| 1990 | 16.95 | 10.52 | 35.67 | 13.32 | 2.71 | 10.94 | 26.16 | 7.39 | 7.43 | 6.86 | 6.95 | 5.8 | 18.7 | 2.57 | 79.17 | 92.8 | 171.97 |
| 1991 | 17.16 | 10.56 | 36.01 | 13.36 | 2.69 | 11.05 | 26.57 | 7.43 | 7.46 | 6.89 | 7.08 | 5.84 | 18.96 | 2.46 | 79.78 | 93.74 | 173.52 |
| 1992 | 17.37 | 10.61 | 36.35 | 13.39 | 2.67 | 11.16 | 26.99 | 7.48 | 7.49 | 6.92 | 7.21 | 5.89 | 19.22 | 2.35 | 80.39 | 94.71 | 175.1 |
| 1993 | 17.59 | 10.65 | 36.7 | 13.42 | 2.65 | 11.27 | 27.42 | 7.53 | 7.53 | 6.96 | 7.34 | 5.94 | 19.49 | 2.25 | 81.01 | 95.73 | 176.74 |
| 1994 | 17.8 | 10.7 | 37.05 | 13.45 | 2.63 | 11.39 | 27.85 | 7.57 | 7.56 | 6.99 | 7.48 | 5.98 | 19.75 | 2.15 | 81.63 | 96.72 | 178.35 |
| 1995 | 18.02 | 10.75 | 37.41 | 13.48 | 2.61 | 11.5 | 28.28 | 7.62 | 7.59 | 7.03 | 7.61 | 6.03 | 20.03 | 2.05 | 82.27 | 97.74 | 180.01 |
| 1996 | 18.24 | 10.79 | 37.78 | 13.51 | 2.59 | 11.62 | 28.73 | 7.66 | 7.62 | 7.06 | 7.75 | 6.08 | 20.3 | 1.96 | 82.91 | 98.78 | 181.69 |
| 1997 | 18.47 | 10.84 | 38.15 | 13.54 | 2.57 | 11.74 | 29.18 | 7.71 | 7.66 | 7.09 | 7.9 | 6.13 | 20.58 | 1.86 | 83.57 | 99.85 | 183.42 |
| 1998 | 18.69 | 10.89 | 38.52 | 13.57 | 2.55 | 11.86 | 29.63 | 7.76 | 7.69 | 7.13 | 8.04 | 6.17 | 20.86 | 1.77 | 84.22 | 100.91 | 185.13 |
| 1999 | 18.99 | 11 | 39.06 | 13.71 | 2.55 | 11.98 | 30.11 | 7.81 | 7.72 | 7.16 | 8.19 | 6.23 | 21.2 | 1.78 | 85.31 | 102.18 | 187.49 |
| 2000 | 19.3 | 11.11 | 39.61 | 13.84 | 2.54 | 12.11 | 30.59 | 7.86 | 7.76 | 7.2 | 8.34 | 6.28 | 21.54 | 1.79 | 86.4 | 103.47 | 189.87 |
| 2001 | 19.61 | 11.23 | 40.17 | 13.97 | 2.54 | 12.23 | 31.08 | 7.92 | 7.8 | 7.24 | 8.5 | 6.34 | 21.89 | 1.8 | 87.52 | 104.8 | 192.32 |
| 2002 | 19.92 | 11.34 | 40.73 | 14.11 | 2.54 | 12.36 | 31.58 | 7.97 | 7.83 | 7.28 | 8.66 | 6.4 | 22.24 | 1.81 | 88.64 | 106.13 | 194.77 |
| 2003 | 20.24 | 11.46 | 41.31 | 14.25 | 2.53 | 12.49 | 32.09 | 8.02 | 7.87 | 7.31 | 8.82 | 6.45 | 22.59 | 1.82 | 89.79 | 107.46 | 197.25 |
| 2004 | 20.56 | 11.57 | 41.89 | 14.39 | 2.53 | 12.62 | 32.6 | 8.08 | 7.91 | 7.35 | 8.98 | 6.51 | 22.96 | 1.83 | 90.94 | 108.84 | 199.78 |
| 2005 | 20.88 | 11.69 | 42.48 | 14.53 | 2.53 | 12.75 | 33.12 | 8.13 | 7.94 | 7.39 | 9.15 | 6.57 | 23.32 | 1.84 | 92.11 | 110.21 | 202.32 |
| 2006 | 21.21 | 11.81 | 43.08 | 14.67 | 2.52 | 12.88 | 33.65 | 8.18 | 7.98 | 7.43 | 9.32 | 6.63 | 23.7 | 1.86 | 93.29 | 111.63 | 204.92 |
| 2007 | 21.54 | 11.94 | 43.69 | 14.81 | 2.52 | 13.01 | 34.19 | 8.24 | 8.02 | 7.46 | 9.49 | 6.68 | 24.08 | 1.87 | 94.5 | 113.04 | 207.54 |
| 2008 | 21.88 | 12.06 | 44.31 | 14.96 | 2.51 | 13.15 | 34.73 | 8.29 | 8.06 | 7.5 | 9.66 | 6.74 | 24.46 | 1.88 | 95.72 | 114.47 | 210.19 |
| 2009 | 22.22 | 12.18 | 44.94 | 15.11 | 2.51 | 13.28 | 35.29 | 8.35 | 8.09 | 7.54 | 9.84 | 6.8 | 24.85 | 1.89 | 96.96 | 115.93 | 212.89 |
| 2010 | 22.57 | 12.31 | 45.58 | 15.26 | 2.51 | 13.42 | 35.85 | 8.4 | 8.13 | 7.58 | 10.02 | 6.86 | 25.24 | 1.9 | 98.23 | 117.4 | 215.63 |
| 2011 | 22.92 | 12.44 | 46.23 | 15.41 | 2.5 | 13.56 | 36.42 | 8.46 | 8.17 | 7.62 | 10.21 | 6.92 | 25.64 | 1.91 | 99.5 | 118.91 | 218.41 |
| 2012 | 23.27 | 12.57 | 46.88 | 15.56 | 2.5 | 13.7 | 37 | 8.52 | 8.21 | 7.65 | 10.4 | 6.99 | 26.05 | 1.93 | 100.78 | 120.45 | 221.23 |
| 2013 | 23.63 | 12.7 | 47.55 | 15.72 | 2.49 | 13.84 | 37.59 | 8.57 | 8.24 | 7.69 | 10.59 | 7.05 | 26.46 | 1.94 | 102.09 | 121.97 | 224.06 |
| 2014 | 23.99 | 12.83 | 48.23 | 15.88 | 2.49 | 13.99 | 38.18 | 8.63 | 8.28 | 7.73 | 10.78 | 7.11 | 26.88 | 1.95 | 103.42 | 123.53 | 226.95 |
| Final | 24.36 | 12.97 | 48.92 | 16.04 | 2.48 | 14.13 | 38.79 | 8.68 | 8.32 | 7.77 | 10.98 | 7.17 | 27.3 | 1.96 | 104.77 | 125.1 | 229.87 |

**Total Drain by species at 100% reduction in chip markets over 1 year (80% availability)**

| | BF MMCF | RS MMCF | WP MMCF | H MMCF | OS MMCF | SM MMCF | RM MMCF | YB MMCF | PB MMCF | B MMCF | WA MMCF | A MMCF | RO MMCF | OH MMCF | TOT SW MMCF | TOT HW MMCF | GRAND TOTAL MMCF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1983 | 5.78 | 5.74 | 14.46 | 8.5 | 2.98 | 1.67 | 5.67 | 2.85 | 2.48 | 2.66 | 0.77 | 0.78 | 5.35 | 10.19 | 37.46 | 32.42 | 69.88 |
| 1984 | 5.86 | 5.76 | 14.6 | 8.54 | 2.98 | 1.69 | 5.78 | 2.87 | 2.5 | 2.68 | 0.8 | 0.79 | 5.47 | 9.89 | 37.74 | 32.47 | 70.21 |
| 1985 | 5.95 | 5.78 | 14.75 | 8.58 | 2.98 | 1.72 | 5.88 | 2.89 | 2.52 | 2.7 | 0.82 | 0.8 | 5.6 | 9.6 | 38.04 | 32.53 | 70.57 |
| 1986 | 6.04 | 5.81 | 14.89 | 8.62 | 2.98 | 1.75 | 5.99 | 2.92 | 2.55 | 2.72 | 0.84 | 0.81 | 5.73 | 9.32 | 38.34 | 32.63 | 70.97 |
| 1987 | 6.14 | 5.83 | 15.04 | 8.66 | 2.98 | 1.77 | 6.09 | 2.94 | 2.57 | 2.74 | 0.86 | 0.82 | 5.86 | 9.05 | 38.65 | 32.7 | 71.35 |
| 1988 | 6.23 | 5.85 | 15.19 | 8.7 | 2.98 | 1.8 | 6.2 | 2.96 | 2.6 | 2.77 | 0.88 | 0.83 | 5.99 | 8.78 | 38.95 | 32.81 | 71.76 |
| 1989 | 6.32 | 5.87 | 15.34 | 8.74 | 2.98 | 1.83 | 6.31 | 2.99 | 2.62 | 2.79 | 0.9 | 0.84 | 6.12 | 8.53 | 39.25 | 32.93 | 72.18 |
| 1990 | 6.42 | 5.89 | 15.49 | 8.78 | 2.99 | 1.86 | 6.42 | 3.01 | 2.64 | 2.81 | 0.93 | 0.85 | 6.26 | 8.28 | 39.57 | 33.06 | 72.63 |
| 1991 | 6.52 | 5.91 | 15.65 | 8.82 | 2.99 | 1.88 | 6.54 | 3.04 | 2.67 | 2.83 | 0.95 | 0.86 | 6.39 | 8.04 | 39.89 | 33.2 | 73.09 |
| 1992 | 6.62 | 5.93 | 15.81 | 8.86 | 2.99 | 1.91 | 6.65 | 3.06 | 2.69 | 2.85 | 0.98 | 0.87 | 6.52 | 7.81 | 40.21 | 33.34 | 73.55 |
| 1993 | 6.72 | 5.96 | 15.97 | 8.9 | 2.99 | 1.94 | 6.77 | 3.09 | 2.72 | 2.88 | 1 | 0.88 | 6.66 | 7.58 | 40.54 | 33.52 | 74.06 |
| 1994 | 6.82 | 5.98 | 16.14 | 8.95 | 2.99 | 1.97 | 6.89 | 3.11 | 2.74 | 2.9 | 1.03 | 0.89 | 6.8 | 7.36 | 40.88 | 33.69 | 74.57 |
| 1995 | 6.92 | 6 | 16.31 | 8.99 | 2.99 | 2 | 7.01 | 3.13 | 2.76 | 2.92 | 1.05 | 0.9 | 6.93 | 7.15 | 41.21 | 33.85 | 75.06 |
| 1996 | 7.02 | 6.03 | 16.48 | 9.03 | 2.99 | 2.03 | 7.13 | 3.16 | 2.79 | 2.94 | 1.08 | 0.91 | 7.07 | 6.95 | 41.55 | 34.06 | 75.61 |
| 1997 | 7.13 | 6.05 | 16.65 | 9.07 | 2.99 | 2.06 | 7.25 | 3.18 | 2.81 | 2.96 | 1.1 | 0.93 | 7.21 | 6.75 | 41.89 | 34.25 | 76.14 |
| 1998 | 5.24 | 3.37 | 11.33 | 6.12 | 2.29 | 1.99 | 6.98 | 3.01 | 2.63 | 2.89 | 1.03 | 0.74 | 6.06 | 1.1 | 28.35 | 26.43 | 54.78 |
| 1999 | 5.35 | 3.4 | 11.51 | 6.17 | 2.29 | 2.02 | 7.11 | 3.04 | 2.66 | 2.91 | 1.06 | 0.75 | 6.19 | 1.1 | 28.72 | 26.84 | 55.56 |
| 2000 | 5.46 | 3.42 | 11.7 | 6.22 | 2.29 | 2.05 | 7.24 | 3.06 | 2.68 | 2.93 | 1.09 | 0.76 | 6.32 | 1.1 | 29.09 | 27.23 | 56.32 |
| 2001 | 5.58 | 3.45 | 11.89 | 6.28 | 2.3 | 2.09 | 7.37 | 3.09 | 2.71 | 2.96 | 1.12 | 0.77 | 6.45 | 1.1 | 29.5 | 27.66 | 57.16 |
| 2002 | 5.69 | 3.48 | 12.08 | 6.34 | 2.3 | 2.12 | 7.5 | 3.12 | 2.73 | 2.98 | 1.15 | 0.79 | 6.58 | 1.1 | 29.89 | 28.07 | 57.96 |
| 2003 | 5.81 | 3.51 | 12.28 | 6.39 | 2.3 | 2.15 | 7.64 | 3.14 | 2.76 | 3 | 1.18 | 0.8 | 6.71 | 1.09 | 30.29 | 28.47 | 58.76 |
| 2004 | 5.93 | 3.53 | 12.48 | 6.45 | 2.3 | 2.18 | 7.78 | 3.17 | 2.78 | 3.02 | 1.21 | 0.81 | 6.84 | 1.09 | 30.69 | 28.88 | 59.57 |
| 2005 | 6.05 | 3.56 | 12.69 | 6.51 | 2.31 | 2.22 | 7.92 | 3.2 | 2.8 | 3.05 | 1.24 | 0.82 | 6.97 | 1.09 | 31.12 | 29.31 | 60.43 |
| 2006 | 6.17 | 3.59 | 12.89 | 6.57 | 2.31 | 2.25 | 8.06 | 3.22 | 2.83 | 3.07 | 1.27 | 0.84 | 7.12 | 1.09 | 31.53 | 29.75 | 61.28 |
| 2007 | 6.3 | 3.62 | 13.1 | 6.63 | 2.31 | 2.29 | 8.2 | 3.25 | 2.85 | 3.1 | 1.3 | 0.85 | 7.28 | 1.08 | 31.96 | 30.2 | 62.16 |
| 2008 | 6.42 | 3.65 | 13.32 | 6.69 | 2.31 | 2.32 | 8.35 | 3.28 | 2.88 | 3.12 | 1.34 | 0.86 | 7.43 | 1.08 | 32.39 | 30.66 | 63.05 |
| 2009 | 6.55 | 3.68 | 13.54 | 6.75 | 2.31 | 2.36 | 8.5 | 3.31 | 2.9 | 3.14 | 1.37 | 0.88 | 7.58 | 1.08 | 32.83 | 31.12 | 63.95 |
| 2010 | 6.68 | 3.71 | 13.76 | 6.81 | 2.32 | 2.39 | 8.65 | 3.33 | 2.93 | 3.17 | 1.41 | 0.89 | 7.74 | 1.07 | 33.28 | 31.58 | 64.86 |
| 2011 | 6.81 | 3.74 | 13.98 | 6.87 | 2.32 | 2.43 | 8.8 | 3.36 | 2.95 | 3.19 | 1.44 | 0.9 | 7.9 | 1.07 | 33.72 | 32.04 | 65.76 |
| 2012 | 6.94 | 3.77 | 14.21 | 6.93 | 2.32 | 2.47 | 8.95 | 3.39 | 2.98 | 3.22 | 1.48 | 0.92 | 8.05 | 1.07 | 34.17 | 32.53 | 66.7 |
| 2013 | 7.08 | 3.8 | 14.44 | 6.99 | 2.32 | 2.5 | 9.11 | 3.42 | 3 | 3.24 | 1.51 | 0.93 | 8.21 | 1.06 | 34.63 | 32.98 | 67.61 |
| 2014 | 7.22 | 3.83 | 14.68 | 7.06 | 2.32 | 2.54 | 9.27 | 3.45 | 3.02 | 3.26 | 1.55 | 0.95 | 8.37 | 1.06 | 35.11 | 33.47 | 68.58 |
| Final | 7.36 | 3.86 | 14.92 | 7.12 | 2.33 | 2.58 | 9.43 | 3.48 | 3.05 | 3.29 | 1.59 | 0.96 | 8.54 | 1.05 | 35.59 | 33.97 | 69.56 |

**Total Growth by species at 100% reduction in chip markets over 1 year (60% availability)**

| | BF MMCF | RS MMCF | WP MMCF | H MMCF | OS MMCF | SM MMCF | RM MMCF | YB MMCF | PB MMCF | B MMCF | WA MMCF | A MMCF | RO MMCF | OH MMCF | TOT SW MMCF | TOT HW MMCF | GRAND TOTAL MMCF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1983 | 11.64 | 7.66 | 25.07 | 9.82 | 2.12 | 7.64 | 17.59 | 5.3 | 5.41 | 4.97 | 4.58 | 4.12 | 12.72 | 2.58 | 56.31 | 64.91 | 121.22 |
| 1984 | 11.74 | 7.66 | 25.21 | 9.79 | 2.09 | 7.72 | 17.85 | 5.33 | 5.43 | 4.99 | 4.66 | 4.15 | 12.88 | 2.43 | 56.49 | 65.44 | 121.93 |
| 1985 | 11.85 | 7.66 | 25.35 | 9.76 | 2.06 | 7.79 | 18.13 | 5.36 | 5.45 | 5.01 | 4.75 | 4.18 | 13.03 | 2.29 | 56.68 | 65.99 | 122.67 |
| 1986 | 11.95 | 7.66 | 25.49 | 9.73 | 2.03 | 7.87 | 18.4 | 5.39 | 5.47 | 5.04 | 4.83 | 4.2 | 13.19 | 2.16 | 56.86 | 66.55 | 123.41 |
| 1987 | 12.05 | 7.67 | 25.64 | 9.71 | 2 | 7.95 | 18.68 | 5.42 | 5.49 | 5.06 | 4.91 | 4.23 | 13.34 | 2.02 | 57.07 | 67.1 | 124.17 |
| 1988 | 12.15 | 7.67 | 25.78 | 9.67 | 1.97 | 8.03 | 18.96 | 5.45 | 5.51 | 5.08 | 5 | 4.26 | 13.5 | 1.9 | 57.24 | 67.69 | 124.93 |
| 1989 | 12.25 | 7.67 | 25.93 | 9.64 | 1.93 | 8.11 | 19.25 | 5.47 | 5.53 | 5.1 | 5.09 | 4.29 | 13.66 | 1.77 | 57.42 | 68.27 | 125.69 |
| 1990 | 12.34 | 7.67 | 26.08 | 9.61 | 1.9 | 8.19 | 19.54 | 5.5 | 5.55 | 5.13 | 5.18 | 4.32 | 13.82 | 1.65 | 57.6 | 68.88 | 126.48 |
| #### | 12.44 | 7.67 | 26.23 | 9.57 | 1.87 | 8.27 | 19.84 | 5.53 | 5.57 | 5.15 | 5.27 | 4.35 | 13.99 | 1.53 | 57.78 | 69.5 | 127.28 |
| 1992 | 12.54 | 7.67 | 26.37 | 9.53 | 1.83 | 8.35 | 20.14 | 5.56 | 5.6 | 5.17 | 5.36 | 4.38 | 14.15 | 1.41 | 57.94 | 70.12 | 128.06 |
| 1993 | 12.64 | 7.67 | 26.52 | 9.5 | 1.8 | 8.44 | 20.44 | 5.59 | 5.62 | 5.19 | 5.45 | 4.42 | 14.31 | 1.3 | 58.13 | 70.76 | 128.89 |
| 1994 | 12.73 | 7.67 | 26.67 | 9.46 | 1.76 | 8.52 | 20.75 | 5.62 | 5.64 | 5.22 | 5.54 | 4.45 | 14.48 | 1.19 | 58.29 | 71.41 | 129.7 |
| 1995 | 12.83 | 7.67 | 26.83 | 9.41 | 1.72 | 8.61 | 21.06 | 5.65 | 5.66 | 5.24 | 5.64 | 4.48 | 14.65 | 1.08 | 58.46 | 72.07 | 130.53 |
| 1996 | 12.92 | 7.67 | 26.98 | 9.37 | 1.69 | 8.69 | 21.38 | 5.67 | 5.68 | 5.26 | 5.73 | 4.51 | 14.82 | 0.97 | 58.63 | 72.71 | 131.34 |
| 1997 | 13.01 | 7.66 | 27.13 | 9.32 | 1.65 | 8.78 | 21.7 | 5.7 | 5.7 | 5.28 | 5.83 | 4.54 | 14.98 | 0.87 | 58.77 | 73.38 | 132.15 |
| 1998 | 13.1 | 7.66 | 27.28 | 9.28 | 1.61 | 8.87 | 22.03 | 5.73 | 5.72 | 5.31 | 5.93 | 4.57 | 15.16 | 0.77 | 58.93 | 74.09 | 133.02 |
| 1999 | 13.27 | 7.72 | 27.6 | 9.33 | 1.59 | 8.96 | 22.37 | 5.77 | 5.75 | 5.33 | 6.04 | 4.61 | 15.38 | 0.77 | 59.51 | 74.98 | 134.49 |
| 2000 | 13.43 | 7.78 | 27.91 | 9.38 | 1.56 | 9.05 | 22.72 | 5.8 | 5.77 | 5.36 | 6.14 | 4.65 | 15.6 | 0.77 | 60.06 | 75.86 | 135.92 |
| 2001 | 13.6 | 7.84 | 28.23 | 9.44 | 1.54 | 9.14 | 23.07 | 5.83 | 5.8 | 5.38 | 6.25 | 4.69 | 15.83 | 0.77 | 60.65 | 76.76 | 137.41 |
| 2002 | 13.76 | 7.9 | 28.55 | 9.49 | 1.52 | 9.23 | 23.43 | 5.87 | 5.82 | 5.41 | 6.36 | 4.73 | 16.06 | 0.77 | 61.22 | 77.68 | 138.9 |
| 2003 | 13.93 | 7.97 | 28.88 | 9.55 | 1.5 | 9.33 | 23.79 | 5.9 | 5.85 | 5.43 | 6.47 | 4.76 | 16.3 | 0.77 | 61.83 | 78.6 | 140.43 |
| 2004 | 14.09 | 8.03 | 29.21 | 9.6 | 1.47 | 9.42 | 24.16 | 5.94 | 5.87 | 5.46 | 6.59 | 4.8 | 16.54 | 0.77 | 62.4 | 79.55 | 141.95 |
| 2005 | 14.26 | 8.09 | 29.54 | 9.65 | 1.45 | 9.52 | 24.54 | 5.97 | 5.9 | 5.49 | 6.7 | 4.84 | 16.78 | 0.77 | 62.99 | 80.51 | 143.5 |
| 2006 | 14.42 | 8.16 | 29.88 | 9.71 | 1.42 | 9.62 | 24.92 | 6.01 | 5.92 | 5.51 | 6.82 | 4.88 | 17.02 | 0.77 | 63.59 | 81.47 | 145.06 |
| 2007 | 14.59 | 8.22 | 30.22 | 9.76 | 1.4 | 9.72 | 25.3 | 6.04 | 5.95 | 5.54 | 6.94 | 4.92 | 17.27 | 0.77 | 64.19 | 82.45 | 146.64 |
| 2008 | 14.76 | 8.29 | 30.56 | 9.82 | 1.37 | 9.81 | 25.69 | 6.08 | 5.97 | 5.56 | 7.06 | 4.96 | 17.52 | 0.77 | 64.8 | 83.42 | 148.22 |
| 2009 | 14.92 | 8.35 | 30.91 | 9.87 | 1.35 | 9.91 | 26.09 | 6.11 | 6 | 5.59 | 7.18 | 5.01 | 17.77 | 0.77 | 65.4 | 84.43 | 149.83 |
| 2010 | 15.09 | 8.42 | 31.26 | 9.93 | 1.32 | 10.02 | 26.49 | 6.15 | 6.03 | 5.62 | 7.31 | 5.05 | 18.02 | 0.77 | 66.02 | 85.46 | 151.48 |
| #### | 15.26 | 8.48 | 31.62 | 9.98 | 1.29 | 10.12 | 26.9 | 6.18 | 6.05 | 5.64 | 7.43 | 5.09 | 18.28 | 0.77 | 66.63 | 86.46 | 153.09 |
| 2012 | 15.43 | 8.55 | 31.97 | 10.04 | 1.26 | 10.22 | 27.32 | 6.22 | 6.08 | 5.67 | 7.56 | 5.13 | 18.54 | 0.77 | 67.25 | 87.51 | 154.76 |
| 2013 | 15.59 | 8.62 | 32.33 | 10.09 | 1.23 | 10.33 | 27.74 | 6.25 | 6.1 | 5.69 | 7.69 | 5.17 | 18.81 | 0.77 | 67.86 | 88.55 | 156.41 |
| 2014 | 15.76 | 8.69 | 32.7 | 10.15 | 1.2 | 10.43 | 28.16 | 6.29 | 6.13 | 5.72 | 7.82 | 5.22 | 19.08 | 0.77 | 68.5 | 89.62 | 158.12 |
| Final | 15.92 | 8.76 | 33.06 | 10.21 | 1.17 | 10.54 | 28.6 | 6.32 | 6.15 | 5.75 | 7.96 | 5.26 | 19.35 | 0.77 | 69.12 | 90.7 | 159.82 |

**Total Drain by species at 100% reduction in chip markets over 1 year (60% availability)**

| | BF MMCF | RS MMCF | WP MMCF | H MMCF | OS MMCF | SM MMCF | RM MMCF | YB MMCF | PB MMCF | B MMCF | WA MMCF | A MMCF | RO MMCF | OH MMCF | TOT SW MMCF | TOT HW MMCF | GRAND TOTAL MMCF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1983 | 5.68 | 5.62 | 14.03 | 7.97 | 2.94 | 1.33 | 4.75 | 2.46 | 2.1 | 2.12 | 0.76 | 0.72 | 5.35 | 10.14 | 36.24 | 29.73 | 65.97 |
| 1984 | 5.76 | 5.64 | 14.16 | 8 | 2.94 | 1.35 | 4.83 | 2.48 | 2.12 | 2.14 | 0.78 | 0.73 | 5.47 | 9.84 | 36.5 | 29.74 | 66.24 |
| 1985 | 5.85 | 5.66 | 14.29 | 8.03 | 2.94 | 1.37 | 4.92 | 2.5 | 2.14 | 2.15 | 0.8 | 0.74 | 5.6 | 9.55 | 36.77 | 29.77 | 66.54 |
| 1986 | 5.94 | 5.68 | 14.42 | 8.06 | 2.94 | 1.39 | 5 | 2.51 | 2.16 | 2.17 | 0.82 | 0.75 | 5.73 | 9.27 | 37.04 | 29.8 | 66.84 |
| 1987 | 6.03 | 5.7 | 14.56 | 8.09 | 2.94 | 1.42 | 5.09 | 2.53 | 2.18 | 2.19 | 0.84 | 0.76 | 5.86 | 8.99 | 37.32 | 29.86 | 67.18 |
| 1988 | 6.12 | 5.72 | 14.7 | 8.12 | 2.94 | 1.44 | 5.18 | 2.55 | 2.2 | 2.2 | 0.86 | 0.77 | 5.99 | 8.73 | 37.6 | 29.92 | 67.52 |
| 1989 | 6.21 | 5.74 | 14.84 | 8.15 | 2.94 | 1.46 | 5.27 | 2.57 | 2.22 | 2.22 | 0.89 | 0.78 | 6.12 | 8.47 | 37.88 | 30 | 67.88 |
| 1990 | 6.3 | 5.76 | 14.98 | 8.17 | 2.94 | 1.48 | 5.36 | 2.59 | 2.24 | 2.24 | 0.91 | 0.79 | 6.26 | 8.22 | 38.15 | 30.09 | 68.24 |
| 1991 | 6.4 | 5.78 | 15.12 | 8.2 | 2.94 | 1.5 | 5.45 | 2.61 | 2.26 | 2.25 | 0.93 | 0.8 | 6.39 | 7.98 | 38.44 | 30.17 | 68.61 |
| 1992 | 6.49 | 5.8 | 15.27 | 8.23 | 2.94 | 1.53 | 5.55 | 2.63 | 2.28 | 2.27 | 0.96 | 0.81 | 6.52 | 7.75 | 38.73 | 30.3 | 69.03 |
| 1993 | 6.59 | 5.82 | 15.42 | 8.26 | 2.94 | 1.55 | 5.64 | 2.65 | 2.3 | 2.29 | 0.98 | 0.82 | 6.66 | 7.52 | 39.03 | 30.41 | 69.44 |
| 1994 | 6.69 | 5.84 | 15.57 | 8.29 | 2.95 | 1.57 | 5.74 | 2.67 | 2.32 | 2.3 | 1.01 | 0.83 | 6.8 | 7.3 | 39.34 | 30.54 | 69.88 |
| 1995 | 6.79 | 5.86 | 15.72 | 8.32 | 2.95 | 1.6 | 5.83 | 2.69 | 2.34 | 2.32 | 1.03 | 0.84 | 6.93 | 7.09 | 39.64 | 30.67 | 70.31 |
| 1996 | 6.89 | 5.88 | 15.88 | 8.35 | 2.95 | 1.62 | 5.93 | 2.71 | 2.36 | 2.34 | 1.06 | 0.85 | 7.07 | 6.89 | 39.95 | 30.83 | 70.78 |
| 1997 | 6.99 | 5.9 | 16.04 | 8.37 | 2.95 | 1.64 | 6.03 | 2.73 | 2.38 | 2.35 | 1.08 | 0.86 | 7.21 | 6.69 | 40.25 | 30.97 | 71.22 |
| 1998 | 5.1 | 3.22 | 10.7 | 5.4 | 2.25 | 1.57 | 5.73 | 2.55 | 2.2 | 2.27 | 1.01 | 0.67 | 6.06 | 1.03 | 26.67 | 23.09 | 49.76 |
| 1999 | 5.2 | 3.24 | 10.87 | 5.44 | 2.25 | 1.59 | 5.84 | 2.57 | 2.22 | 2.29 | 1.04 | 0.68 | 6.19 | 1.03 | 27 | 23.45 | 50.45 |
| 2000 | 5.31 | 3.27 | 11.04 | 5.48 | 2.25 | 1.62 | 5.94 | 2.59 | 2.24 | 2.31 | 1.07 | 0.69 | 6.32 | 1.03 | 27.35 | 23.81 | 51.16 |
| 2001 | 5.42 | 3.29 | 11.22 | 5.52 | 2.25 | 1.64 | 6.05 | 2.61 | 2.26 | 2.32 | 1.09 | 0.7 | 6.45 | 1.03 | 27.7 | 24.15 | 51.85 |
| 2002 | 5.53 | 3.32 | 11.39 | 5.56 | 2.25 | 1.67 | 6.16 | 2.64 | 2.28 | 2.34 | 1.12 | 0.71 | 6.58 | 1.03 | 28.05 | 24.53 | 52.58 |
| 2003 | 5.65 | 3.34 | 11.57 | 5.61 | 2.25 | 1.7 | 6.27 | 2.66 | 2.3 | 2.36 | 1.15 | 0.72 | 6.71 | 1.02 | 28.42 | 24.89 | 53.31 |
| 2004 | 5.76 | 3.37 | 11.76 | 5.65 | 2.25 | 1.72 | 6.38 | 2.68 | 2.32 | 2.38 | 1.18 | 0.74 | 6.84 | 1.02 | 28.79 | 25.26 | 54.05 |
| 2005 | 5.88 | 3.39 | 11.94 | 5.69 | 2.26 | 1.75 | 6.5 | 2.7 | 2.34 | 2.4 | 1.21 | 0.75 | 6.97 | 1.02 | 29.16 | 25.64 | 54.8 |
| 2006 | 6 | 3.42 | 12.13 | 5.73 | 2.26 | 1.78 | 6.61 | 2.72 | 2.36 | 2.41 | 1.25 | 0.76 | 7.12 | 1.01 | 29.54 | 26.02 | 55.56 |
| 2007 | 6.12 | 3.44 | 12.32 | 5.77 | 2.26 | 1.8 | 6.73 | 2.74 | 2.39 | 2.43 | 1.28 | 0.77 | 7.28 | 1.01 | 29.91 | 26.43 | 56.34 |
| 2008 | 6.24 | 3.47 | 12.52 | 5.82 | 2.26 | 1.83 | 6.84 | 2.77 | 2.41 | 2.45 | 1.31 | 0.78 | 7.43 | 1.01 | 30.31 | 26.83 | 57.14 |
| 2009 | 6.36 | 3.5 | 12.72 | 5.86 | 2.26 | 1.86 | 6.96 | 2.79 | 2.43 | 2.47 | 1.34 | 0.8 | 7.58 | 1 | 30.7 | 27.23 | 57.93 |
| 2010 | 6.49 | 3.52 | 12.92 | 5.9 | 2.26 | 1.89 | 7.08 | 2.81 | 2.45 | 2.49 | 1.38 | 0.81 | 7.74 | 1 | 31.09 | 27.65 | 58.74 |
| 2011 | 6.62 | 3.55 | 13.12 | 5.95 | 2.27 | 1.92 | 7.21 | 2.83 | 2.47 | 2.5 | 1.41 | 0.82 | 7.9 | 0.99 | 31.51 | 28.05 | 59.56 |
| 2012 | 6.75 | 3.58 | 13.33 | 5.99 | 2.27 | 1.94 | 7.33 | 2.86 | 2.49 | 2.52 | 1.45 | 0.83 | 8.05 | 0.99 | 31.92 | 28.46 | 60.38 |
| 2013 | 6.88 | 3.6 | 13.54 | 6.03 | 2.27 | 1.97 | 7.46 | 2.88 | 2.51 | 2.54 | 1.48 | 0.85 | 8.21 | 0.98 | 32.32 | 28.88 | 61.2 |
| 2014 | 7.01 | 3.63 | 13.76 | 6.08 | 2.27 | 2 | 7.58 | 2.9 | 2.53 | 2.56 | 1.52 | 0.86 | 8.37 | 0.98 | 32.75 | 29.3 | 62.05 |
| Final | 7.14 | 3.66 | 13.98 | 6.12 | 2.27 | 2.03 | 7.71 | 2.92 | 2.55 | 2.58 | 1.56 | 0.87 | 8.54 | 0.97 | 33.17 | 29.73 | 62.9 |

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The mission of the Natural Resources Network is to enhance interaction among the natural resource research, teaching, and outreach communities in New Hampshire by providing an ongoing mechanism for identifying, addressing and communicating natural resource issues.

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