

# *Impacts of Recycling Technology on North American Fiber Supply and Competitiveness*

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## **ABSTRACT**

This paper discusses results of studies that have involved modeling and projecting evolution of process technology, regional markets, and trade in the North American pulp and paper sector. We found that an economic model simulated accurately the shift toward higher recycling rates that has occurred since the mid-1980s. Long-range projections show that the North American pulp and paper sector will continue to evolve toward significantly higher recycling rates in the 1990s, followed by more gradual increases in recycling in the next century. Fiber supplies are effectively extended with expansion of recycling technologies and a more modest growth in pulpwood consumption. Extended fiber supply and increased recycling will tend to enhance global competitiveness of pulp and paper produced in North America, particularly in the United States. Results are hinged primarily on assumptions about fiber supply, product demand, and adoption of efficient production technologies. Regulatory constraints play only a minor role in developing projections of increased recycling based on our model. Results support a conclusion that availability of improved technology and abundance of recycled fiber resources are primary determinants of increased recycling and global competitiveness in pulp and paper for North America.

## **INTRODUCTION**

Large volumes of wood fiber have been recycled in the United States and worldwide for many years, principally in the pulp and paper sector. Market conditions and availability of technology have largely determined the evolution of paper recycling in North America. Mounting concerns about waste disposal and legislative responses also may have influenced fiber markets and recycling rates.

Recovery of paper for recycling has been increasing in recent years. Annual U.S. recovery was in the range of 33 million metric tons in 1993, a volume which had nearly tripled since 1970 and had nearly doubled since 1980 (AFPA 1994). The increase in paper recovery has been partially a response to declining availability of landfills, long-term environmental, economic, and human health problems associated with landfills and waste incineration, and increasing costs of waste disposal. By increasing recovery of paper for recycling, disposal costs are avoided. Thus, in part, increased recovery of paper for recycling is subsidized to avoid disposal costs.

Expansion of recovery led to cheaper and more abundant supplies of recovered paper, particularly toward the late 1980s and into the 1990s. In addition, consumers in North America apparently became increasingly willing to accept recycled paper, leading to increased demand and substitution of recycled fiber for virgin fiber. These developments in fiber supply and demand, coupled with availability of competitive technology for paper recycling have provided the incentives and framework for a substantial expansion of paper recycling capacity and technology since the mid-1980s.

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## **METHODS**

Over the years, we have sought to develop methods for modeling changes in technologies and fiber markets in the pulp and paper sector. Our methods are based on economic optimization theory, using price-endogenous linear programming. The methodology is available for general application in the Price Endogenous Linear Programming System (see Zhang et al. 1993). Our most recent modeling experience has been in development of the North America Pulp and Paper (NAPAP) Model, in collaboration with Forestry Canada from 1990 to 1992. The NAPAP Model has been used to develop long-range projections of trends in paper recycling pulpwood markets, and dated technological trends of the pulp and paper sector for the USDA Forest Service. Projections illustrated in this report were developed in early 1993 for the 1993 RPA Assessment Update (see Ince, 1994a). Projections are the result of supply and demand analysis and market equilibria computed by the NAPAP Model, with 1986 as the base year. Data and structure of the model have been described elsewhere (Ince, 1994b). The NAPAP Model has been used to make more recent projections, and the model continues to be updated and improved.

Although we cannot fully describe the model in this brief paper, we describe several of its significant behavioral elements related to markets and technology. Those elements include (1) expansion of supply in recovered paper markets in response to increasing waste disposal costs, (2) market responses to consumer acceptance of paper products made from recycled fiber, and (3) industrial expansion of recycling, which is explained in our model as primarily a response to market conditions. We also observe that adoption of recycling technology is projected to have significant impacts on fiber supply and competitiveness in North America. Expansion of recycling technologies will result in extended fiber supply and enhanced competitiveness, particularly for the United States.

## **EXPANSION OF FIBER SUPPLY FOR RECYCLING**

The recovery of paper for recycling in North America, particularly in the United States, increased significantly during the past decade. The increase in recovery coincided with changes in availability of landfills for disposal of municipal solid waste (MSW) since the 1970s. In 1978, approximately 20,000 MSW landfills were operating in the United States; more than 14,000 landfills were closed in subsequent years as a result of environmental risks, operating costs, or limits on capacity. By 1990, only about 6,000 MSW landfills were in operation (Denison and Ruston 1990). In the United States, more than half of the states are now projected to have less than 10 years of remaining landfill capacity.

Although land filling was perhaps once viewed as a benign and efficient option for waste disposal, that perspective has changed substantially, both from a scientific and technical standpoint as well as an economic and public opinion perspective. Basic problems associated with landfills are now widely recognized, including potential for groundwater contamination by landfill leachate and landfill gas emissions. In the United States, billions of dollars have been spent in recent years on remediation and cleanup of abandoned landfills, dumps, and other waste disposal sites. Many communities have faced very substantial costs to cleanup or remedy the contamination problems associated with locally abandoned landfills, or to enhance the performance of existing waste management and disposal systems. Such costs have placed heavy financial burdens on local governments, which must also provide other community services. In addition, landfill sites tend to depress local real estate values due to the nuisance problems of equipment noise, odors, traffic congestion, drifting debris, and attraction of insects and birds.

Consequently, the 1980s witnessed a significant decline in new landfills in the 1980s, a trend toward siting of landfills in more remote locations (in neighboring states or low-income rural communities), and a significant increase in waste disposal costs. According to the National Solid Waste Management Association, between 1982 and 1990, fees for disposal of waste in landfills (tipping fees) increased by 221 percent in the U.S. South, 210 percent in the U.S. West, and 386 percent in the U.S. North (and nearly 500 percent in New England, where tipping fees now exceed \$100, constant 1986 dollars, per ton in many localities). Rapidly escalating tipping fees, along with concern about other economic and environmental problems of landfills, prompted many local and state governments and

other institutions to initiate programs for collecting and sorting materials for recycling to divert waste from landfills and avoid disposal costs.

In estimating U.S. supply functions for recovered paper in the NAPAP Model, we examined landfill tipping fees as a shifter of recovered paper supply. Econometric analysis confirmed a significant positive relationship between landfill tipping fees and increased recovered paper supply since 1980. We observed that increased disposal costs were related to increased recovery of paper for recycling, particularly for categories of paper that were heavily landfilled.

Thus, in the NAPAP Model, we included a representation of behavioral relationships between disposal cost trends and regional supplies of recovered paper. We also included linkages between increased consumption of paper and paperboard and increased supplies of recovered paper. We expect that disposal costs will increase in the future, although at a slower rate of increase than in recent years. Thus, we are projecting that recovered paper supplies will continue to increase, subject ultimately to infrastructure limits on recovery rates. The increasing disposal costs and increasing regional supplies of recovered paper are factors that contribute to projected expansion of recycling technology.

In this paper, we present two scenarios, a Base and a "Waste Reduction" scenario. In the Base scenario, we assumed a gradual decline in the rate of increase for landfill tipping fees, subsiding to an annual rate of 4 percent per year in the late 1990s and into the next century. This results in a gradual decline in the rate of increase for recovered paper supply. We also assumed maximum feasible recovery rates in the range of 60 to 75 percent in the United States, depending on grade of recovered paper. In the Waste Reduction scenario, we assumed that in addition to being stimulated by rising disposal costs, recovered paper supply in the United States would increase at an additional 5 percent per year, subject to upper limits on maximum feasible recovery rates. In this scenario, we also assumed higher maximum feasible recovery rates (80 percent) for the United States. Thus, relative to the Base scenario, the Waste Reduction scenario assumed a more intensive collection and greater future supply of paper for recycling in the United States, in addition to other adjustments discussed in the following sections.

## **TECHNOLOGY STRUCTURE**

In developing the technology structure of the NAPAP Model, we were guided by observation of industry behavior related to utilization of production capacity and investment in new capacity. We observed, as others have, that although technology of the pulp and paper sector maybe complex and diversified, discrete categories of processes exist. We also observed that short-run utilization of production capacity and long-run evolution of capacity both exhibit rationality based on profit-maximizing behavior. In other words, production processes that are more efficient and profitable tend to be utilized more intensively in the short run; in the long run, they tend to gradually displace processes that are not as profitable. Furthermore, as market conditions evolve over time, relative profitability of processes may change as well.

Consequently, we imbedded profit-maximizing behavior into our economic model of the pulp and paper sector, along with a technology structure that was detailed enough to include most major categories of production processes used among the various grades of pulp, paper, and paperboard produced in North America. In the short run, the model finds optimal levels of production among competing regions and processes, by maximizing consumer and producer surplus in the linear programming solution for each year. In the long run, from year to year, the model determines change in capacity for each process using Tobin's q-theory of investment (in which annual capacity expansion for each process depends on the "q-ratio" in each year: the shadow price or marginal benefit of capacity expansion divided by the marginal cost of capacity expansion).

With this type of structure, the annual regional production volumes and annual changes in production capacity for each process are determined by relative production costs and profitability, and prevailing market conditions. Since all of the principal production processes of the pulp and paper sector are represented in the NAPAP Model, encompassing technologies based on both recycled fiber and virgin fiber, the model develops projections of recycling rates as it determines production and ca-

capacity change by process over time. In essence, the economic model is a technology forecasting tool, in that it predicts how products will be made according to discrete production processes, as well as a market forecasting tool.

In the Base scenario, production by process each year was constrained only by existing capacity, and change in capacity for each process was determined by the q-ratio (or relative profitability) as determined by market forces alone. In the Waste Reduction scenario, however, a significant investment tax credit was assumed to be available to promote investment in recycling, thus reducing the cost of capacity expansion. A 20-percent investment tax credit was assumed for processes capable of utilizing recovered paper, with the credit prorated according to the proportion of recycled fiber utilized, simulating a potential government policy incentive for recycling. Such tax credits have been adopted by many States, but not by the Federal tax code.

## **DEMAND ASSUMPTIONS**

In general, we observed that paper and paperboard products made from recycled fiber appear to have met increasing consumer acceptance over the past decade. In some market segments, recycled paper products have actually become preferred products relative to paper products made from virgin fiber. Various governmental entities in the United States, including the Federal government, now have purchasing preferences for recycled paper products. Many purchasers in the private sector have also sought to obtain recycled paper products. This trend is somewhat of a departure from traditional preferences in paper products, which were based primarily on measures of physical quality. In the past, recycled fiber was often viewed as inferior (or “secondary”) to virgin fiber according to measures such as sheet strength or brightness. A combination of improvements in process technology and changes in consumer attitudes has contributed to the changing perspective. Process technologies such as improved press sections in linerboard mills and improved deinking systems in newsprint mills have helped to provide customers with high quality products made from recycled fiber. We also observed that the focus of primary producers of the pulp and paper sector has long been commodity-oriented, so that production processes for recycled paper products are generally designed to produce products that can be competitive with virgin-fiber products.

Consequently, in structuring the NAPAP Model, we defined regional demands only for the 12 major commodity groupings or grades that are the major categories of paper and paperboard grades recognized in North America. We did not distinguish between demand for virgin-fiber commodities or recycled fiber commodities in any of the grades (e.g., in the case of newsprint, we recognized aggregate regional demands for newsprint in the United States and Canada, and for export demand regions, but on the demand side, we did not distinguish between recycled newsprint and virgin-fiber newsprint; both serve the same demand for newsprint).

Consequently, although recycled-fiber processes have unique costs and input requirements differing from virgin-fiber processes in the NAPAP Model, the model simulates unrestrained competition on the demand side. This is a simplification of reality, as indeed markets do differentiate between virgin-fiber and recycled products within the commodity categories, but we observed that the basis for such differentiation appears to be narrowing as a result of improved technology and market acceptance of recycled products. Economic differences between recycled and virgin-fiber technologies are recognized in our model solely by differences in process costs and input requirements needed to produce commodities of similar quality or market acceptance.

The Base scenario was programmed with demand growth assumptions related to projected population and GDP growth in the United States and Canada, and other shifters for overseas export demand growth. No adjustments or restrictions were placed on demand with respect to virgin or recycled fiber content, although minor downward adjustments were made in demand growth for some commodities, reflecting expected impacts of product substitution by plastics and electronic media. The Waste Reduction scenario incorporated the same economic growth assumptions as the Base scenario, but it also included a reduction in demand designed to simulate potential impacts of waste management policies or higher product disposal costs. Thus, in the Waste Reduction scenario, we re-

duced demand by 1 percent per year after 1995, relative to the Base scenario, for all paper and paperboard commodities.

## RESULTS

A sample of NAPAP Model projections is presented to illustrate results obtained from our analysis. Results correspond to the two scenarios developed to examine potential impacts of recycling on the long-range timber outlook (Ince 1994a). Results were obtained from the NAPAP Model, with linkage to the Forest Service TAMM/ATLAS model via exchange of data on timber consumption and supply, through convergent iterative solutions with both models.

Addition of paper recycling capacity continues to be met by increased collection and recovery of paper for recycling, but demand will gradually catch up with supply. While much new recycling capacity has been added at integrated pulp and paper mills, much new capacity is also geared exclusively toward use of recycled fiber. This has created a growing source of stable demand for recycled fiber in North America, which will eventually result in higher prices for recovered paper as demand gradually catches up with supply in the 1990s. Figures 1 and 2 illustrate historical data and NAPAP Model projections of bends in recovered paper prices under the two scenarios for the US. North, where recovered paper prices had declined most significantly in recent years (prices had declined in all US. regions, but the lowest prices were reached in the North and East).

A dramatic increase in old newspaper (ONP) prices is projected to occur toward the middle part of this decade, as demand for recovered paper catches up with supply. Similar increases are projected to occur for old corrugated containers (OCC) and pulp substitutes & high grade deinking. A more prolonged and gradual recovery is projected for mixed grades of recovered paper, reflecting the lower utility and less intensive utilization of mixed wastepaper. However, even prices for mixed paper grades are projected by the NAPAP Model to increase substantially in the decades ahead, as utilization increases. As supplies of recovered paper commodities are projected to be higher in the Waste Reduction scenario, projected prices are lower than those in the Base scenario. However, in both scenarios, substantial price increases for most categories of recovered paper are projected as demand catches up with supply in the late 1990s.

The rate of increase in recycling will tend to decline toward the end of this decade, as prices for recovered paper commodities increase. Figure 3 shows historical data and projected trends in the recyclable paper recovery rate for the United States under both scenarios. Figure 4 shows historical data and projected trends in the recovered paper utilization rate for the United States under both scenarios. The model accurately tracks the aggregate historical changes in U.S. utilization and recovery rates since the mid-1980s, during a period when recovery and recycling increased dramatically. Figures 5 and 6 illustrate historical data and projections of the recovered paper utilization rates in the United States for paper and paperboard commodities, respectively. The model is less accurate in tracking recent historical trends at disaggregated levels, but seems to predict accurately the direction of changes. Note that paperboard has traditionally had higher utilization rates than paper, but utilization rates have been increasing and were projected by our model to continue increasing for both paper and paperboard. The Waste Reduction scenario has a large impact on projected recycling rates in paper production, but much smaller impacts on recycling rates in paperboard.

Figures 7 and 8 illustrate the differences in projected U.S. paper and board consumption between the Waste Reduction and Base scenarios. In both scenarios, total U.S. paper and board consumption was projected to increase, but per-capita consumption actually declines somewhat in the Waste Reduction scenario. Both scenarios resulted in projected consumption trends somewhat lower than actual trends of recent years, suggesting that we may have slightly overestimated impacts of product substitution by plastics and electronic media (at least in the near term).

Pulpwood demand is projected to increase at a more modest rate than it has in recent decades, as a result of increased paper recycling. Figures 9 and 10 illustrate historical data and projected trends in total U.S. pulpwood consumption plus exports. Pulpwood consumption is lower in the Waste Reduc-

tion scenario, with higher recycling and lower consumption of paper and board. In either case, annual U.S. supply of pulpwood is projected to remain in the range of approximately 200 to 250 million cubic meters in the decades ahead. Technological changes favor increased use of hardwood, with hardwood projected to approach 40 percent of U.S. pulpwood supply in the next century.

Increased recycling will extend North American pulpwood supplies. Also, in the early part of the next century, U.S. pulpwood supplies are projected to increase (particularly for softwoods) as a result of extensive tree planting programs of the past decade, particularly in the U.S. South. Hardwood pulpwood supplies will become more limited in the early part of the next century due to projected declines in hardwood timber inventories, particularly in the South. Consequently, delivered softwood pulpwood prices are expected to remain relatively stable in the United States, or perhaps even decline, while delivered hardwood pulpwood prices may continue to increase relative to softwood. Figures 11 and 12 illustrate historical data and projected trends in delivered pulpwood prices in the United States for two major regions, the North (North Eastern and North Central regions) and the South. Hardwood pulpwood is projected to continue gaining in value relative to softwood pulpwood in U.S. markets. On the whole, with increased recycling, U.S. pulpwood prices are projected to remain relatively stable or perhaps decline in the years ahead, contributing to enhanced competitiveness for U.S. producers of pulp and paper products.

The U.S. balance of trade in pulp and paper is projected to swing in favor of exports as fiber supplies are extended with increased recycling. Exports in particular are projected to increase. Figure 13 illustrates historical data and NAPAP Model projections of the U.S. net trade balance for paper and paperboard products computed on the basis of tonnage of primary product imports and exports. The net trade balance has been historically moving toward a positive balance for the United States, and it is projected to reach a positive trade balance by the first decade of the next century. Higher rates of recycling tend to favor improvement in the U.S. trade balance, according to our analysis, based on free trade assumptions and projected evolution of fiber supply, demand, and production technology.

Finally, Figure 14 shows projections of the extent to which market trends in recycling and recycling policies may influence the gross wastepaper disposal burden of the United States (i.e. the volume of paper and board consumed in the United States that is not recovered for domestic recycling or export, and that must therefore be disposed via landfilling, incineration, sewage, or other means). The gross disposal burden had been increasing historically through the 1970s and 1980s, rising from around 40 million metric tonnes in 1970 to over 50 million metric tonnes in 1990. The projected evolution of markets and technology in the Base scenario results in a decline of the wastepaper disposal burden to around 40 million tonnes, and then a gradual increase in the next century. The Waste Reduction scenario, however, results in a substantial decline in the disposal burden, declining to around 20 million tonnes by the year 2020.

## CONCLUSIONS

Our results support the conclusion that availability of improved technology and abundance of recycled fiber resources are primary determinants of increased recycling and global competitiveness in pulp and paper for the United States. Results are hinged primarily on behavioral assumptions about fiber supply, product demand, and adoption of efficient production technologies. Regulatory constraints played a relatively minor role in developing our projections of increased recycling. In the Base scenario, substantial increases in recycling and improvements in competitiveness are projected to occur, without imposition of any regulatory adjustments in our model. In the Waste Reduction scenario, significant adjustments are imposed, including more rapid increases in recovered paper supply, higher maximum feasible recovery rates, tax credits for investment in recycling technology, and reduction in product demand growth reflecting potential impacts of source reduction policies and higher disposal costs. Although the likelihood of such a combination of adjustments maybe small, it is apparent that such adjustments could effectuate even higher recycling rates, lower consumption of paper and board, reduced pulpwood prices, and a substantially reduced wastepaper disposal burden for the United States.

**ACKNOWLEDGEMENTS**

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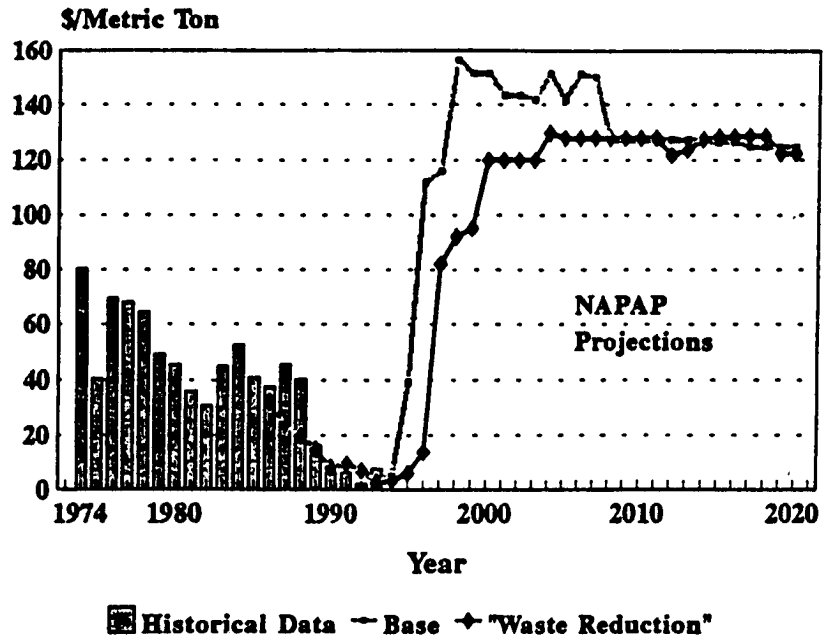


Figure 1. Historical data and NAPAP Model projections of price trends for recovered old newspaper (ONP) in U.S. North under Base and Waste Reduction scenarios.

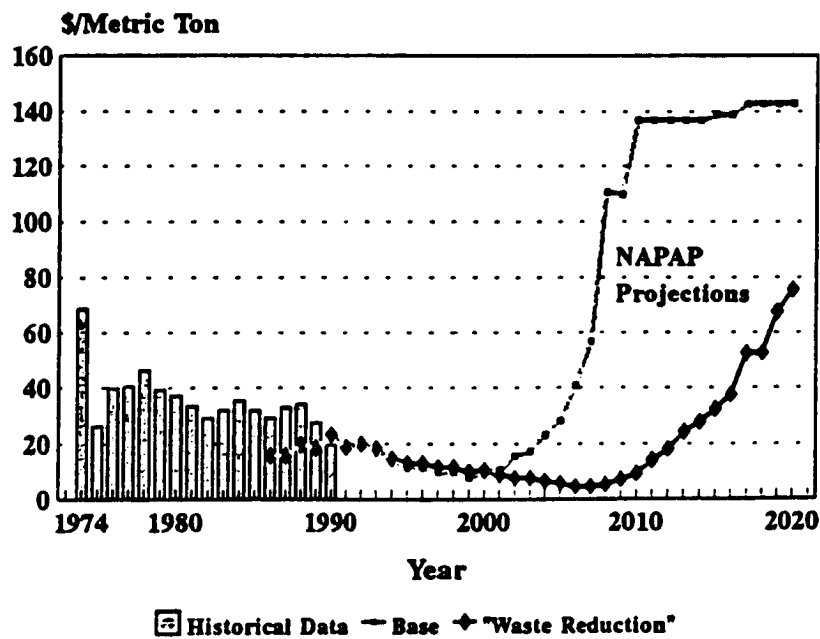


Figure 2. Historical data and projections of price trends for mixed grades of recovered paper in U.S. North.

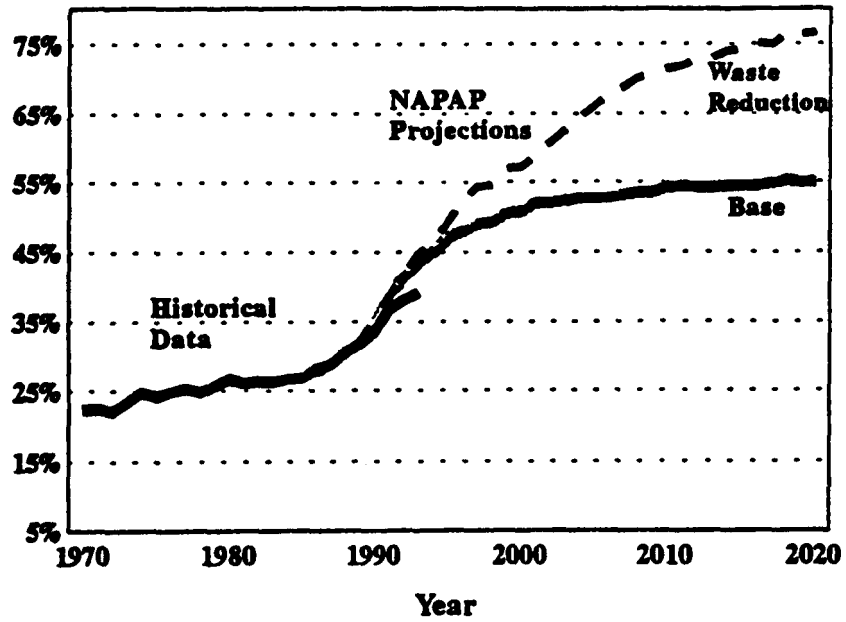


Figure 3. Historical data and projected trends for recovery rate of recyclable paper in the United States.

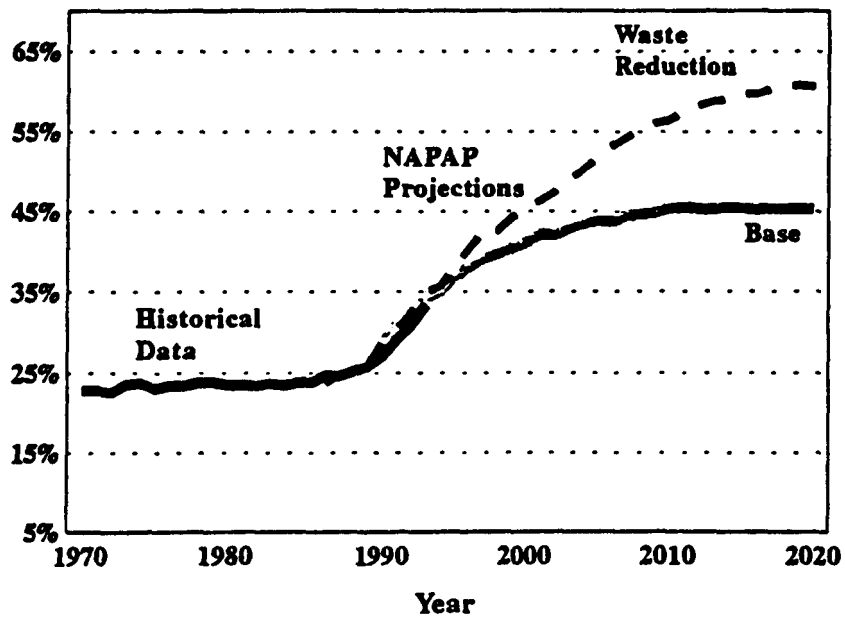


Figure 4. Historical data and projected trends for utilization rate of recyclable paper in the United States.

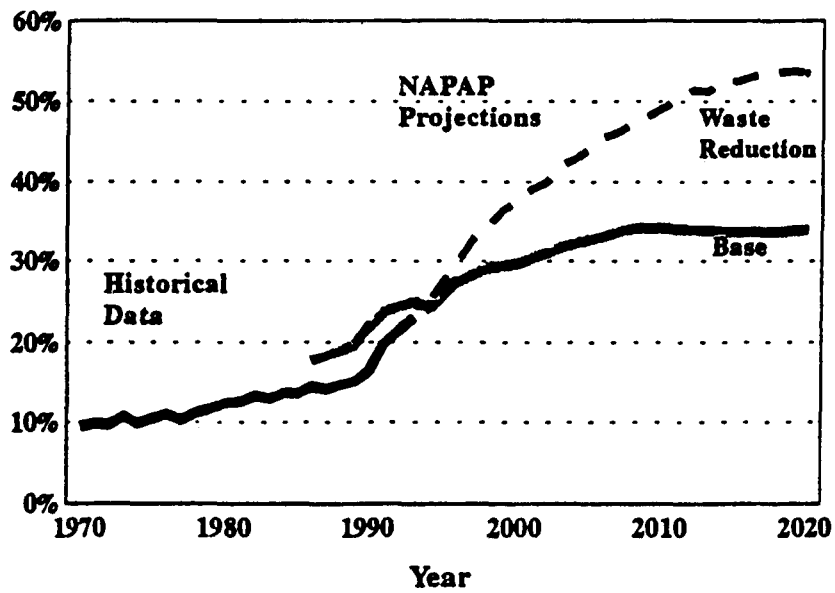


Figure 5. Historical data and projected trends for utilization rate of recovered paper in paper production, excluding paperboard

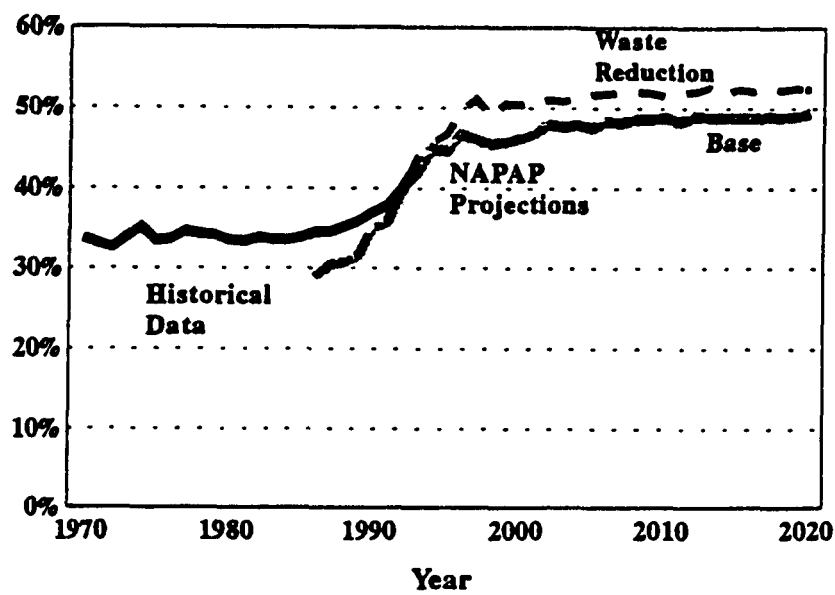


Figure 6. Historical data and projected trends for utilization rate of paperboard.

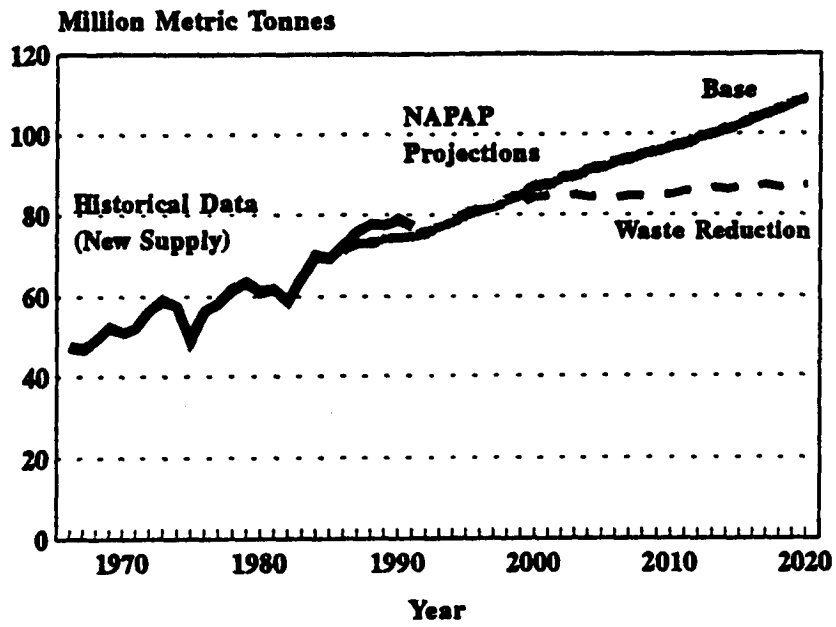


Figure 7. Historical data and projected trends for U.S. paper and board consumption.

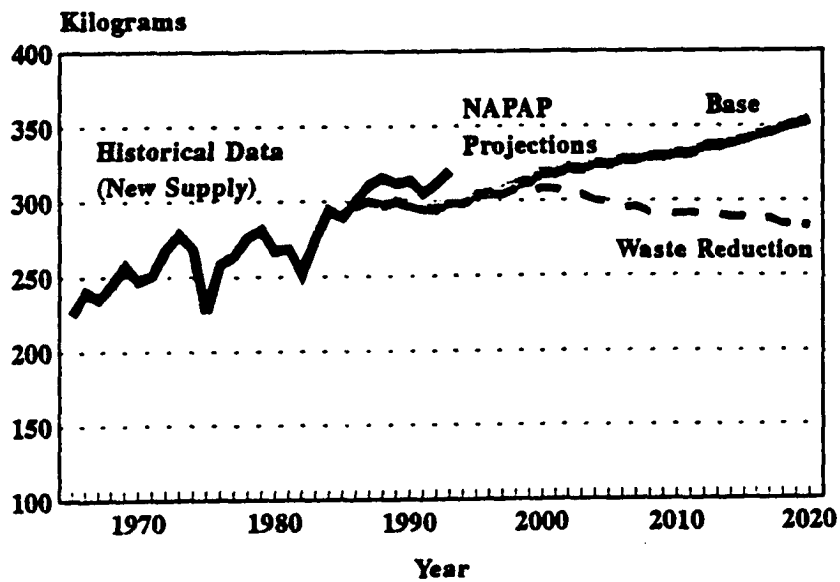


Figure 8. Historical data and projected trends for per capita consumption (new supply) of paper and paperboard (including construction grades).

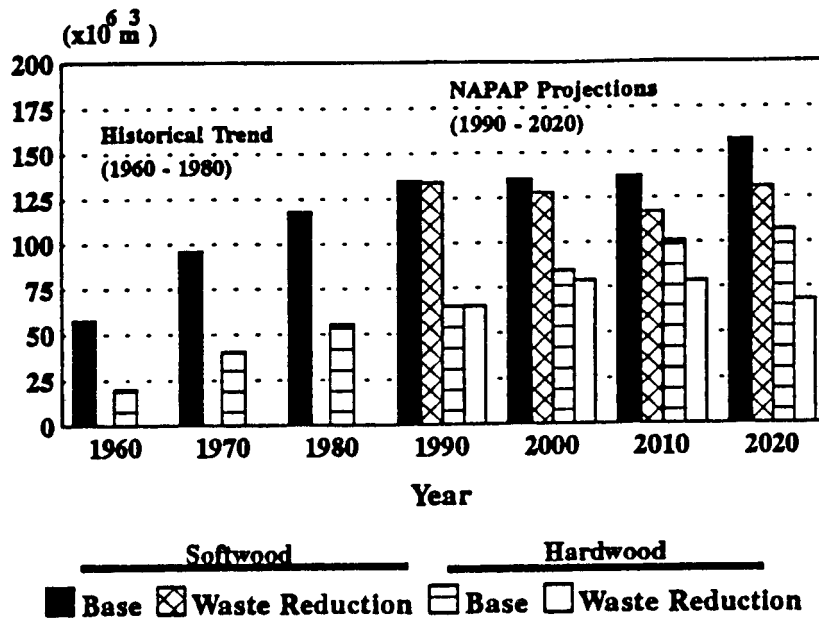


Figure 9. Historical data and projected trends for total U.S. consumption and exports of pulpwood, softwood and hardwood.

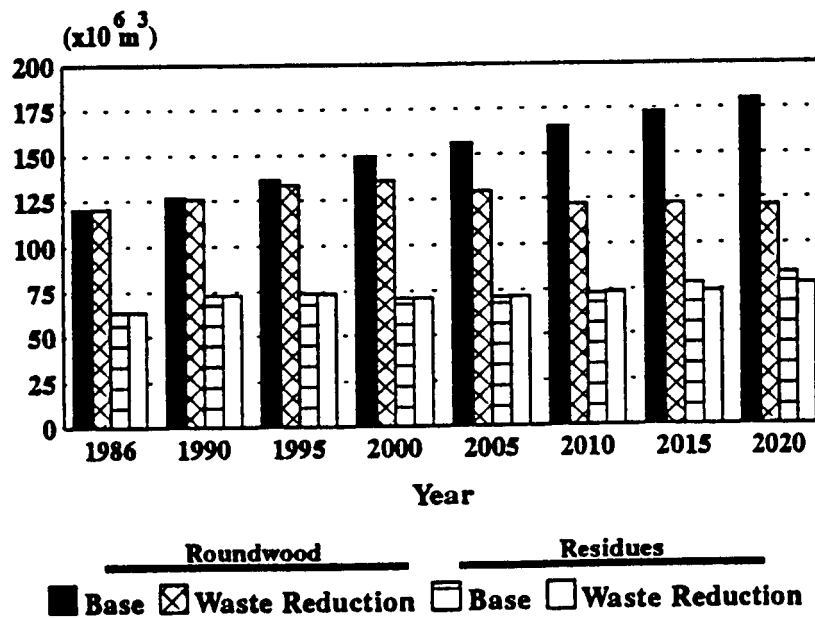


Figure 10. Historical data and projected trends for total U.S. consumption and exports of pulpwood, roundwood and residues.

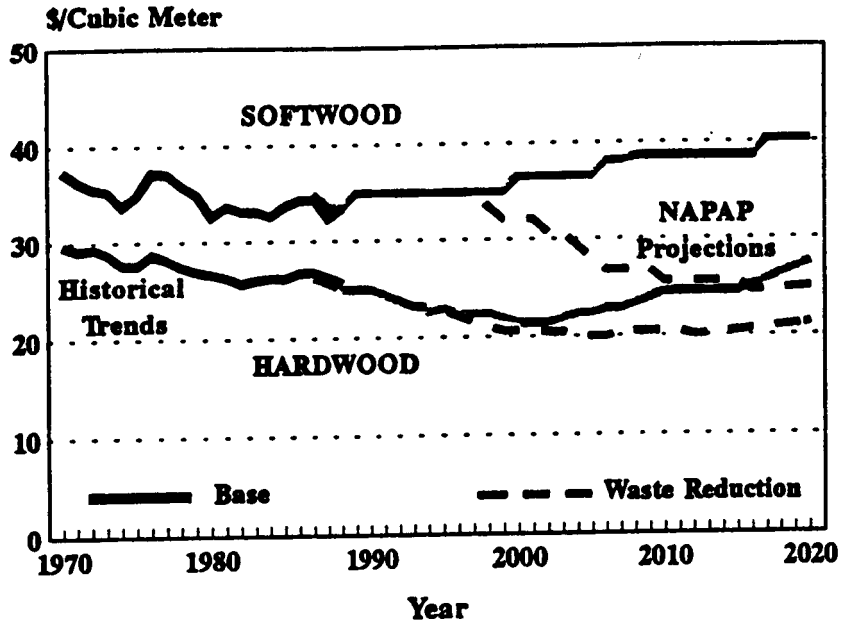


Figure 11. Historical data and projected trends for real prices for pulpwood roundwood for U.S. North.

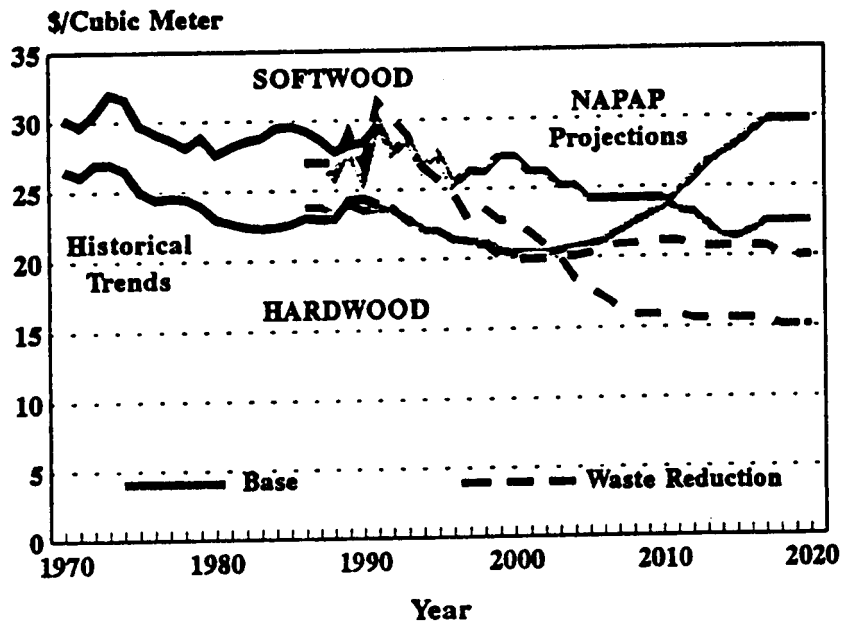


Figure 12. Historical data and projected trends for real prices for pulpwood roundwood for U.S. South.

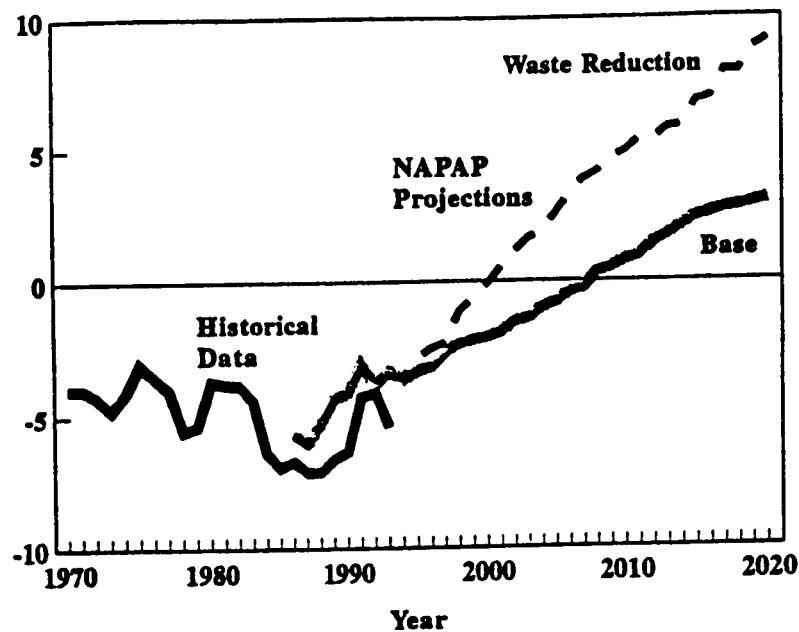


Figure 13. Historical data and projected trends for U.S. trade balance for paper and paperboard (tonnage).

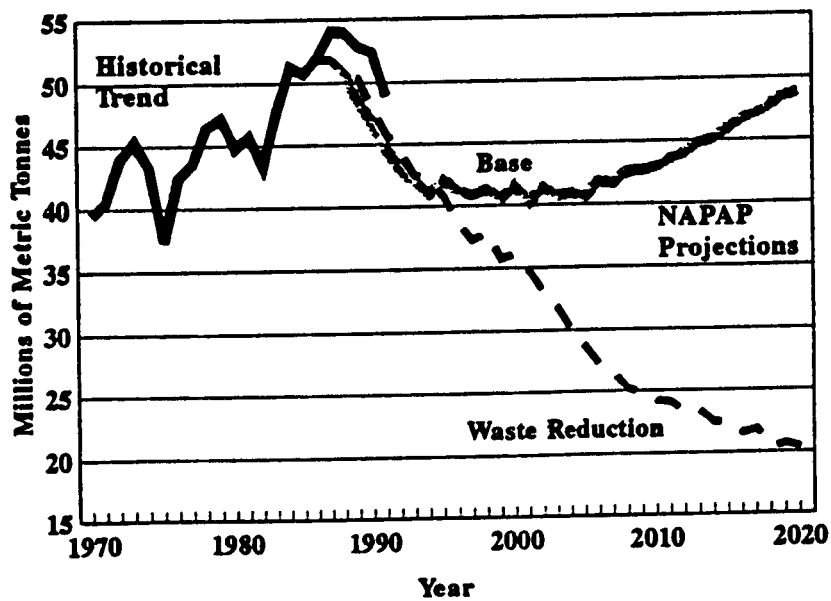


Figure 14. Historical data and projected trends for U.S. gross wastepaper disposal burden (paper and paperboard consumption minus recyclable paper recovery).

on recycled paper