An Examination of Excess Wood Pellet Supply in the United States

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Abstract

The US wood pellet exports—mostly to Europe, Japan, and South Korea—comprised 85 percent of its wood pellet production in the past 20+ years. In this article, we estimate the regional excess supply of wood pellets in the United States using annual data from 1996 to 2021.We use Seemingly Unrelated Regression (SUR) analysis in a profit maximization framework for the South, North, and West regions of the United States. We also include some clean energy policies of the European Union (EU) to examine their potential impact on US wood pellet export volume. Our results show that after application of the low-carbon energy target in the EU, the export volume of the United States has increased, especially in the South region. Elasticity of excess wood pellet supply from the United States was approximately 0.15 in all three regions, and interest rates and energy costs have negative impacts on regional excess supply. Therefore, the recent increase in interest rates and energy costs could slow down the growth of excess supply of wood pellets in the United States.

Demand for clean energy, including bioenergy, has been growing as a result of concerns about global environmental sustainability. Wood pellets are a new forest biomass for bioenergy production and a sustainable and carbon-neutral alternative energy source for fossil-based fuels and other energy sources (Scouse et al. 2017, Kittler et al. 2020, Mehmood 2021). According to Statista (2022), global production of wood pellets increased 32 times, from 1.7 million tons in 2000 to 55 million tons in 2021. The value of wood pellet production was approximately US$11 billion in 2021 and is expected to reach US$24 billion by 2028 (Globenewswire 2021). Wood pellets have many advantages over other biomass, such as higher energy density, homogeneous quality, improved handling and storage properties, and better applicability for different end uses including cooking, grilling, and indoor pellet stoves (Fournel et al. 2015).

Wood pellets release almost three times less carbon emissions than that released by natural gases and almost six times less than by fuel oil; therefore, increasing use of wood pellets is expected to reduce CO_2 emissions (Sjlie et al. 2010, EIA 2021). The many advantages of wood pellets have resulted in global wood pellet production and consumption growing significantly over the past decade, driven by increasing demand in Europe and Asia (European Pellet Council 2019). Because of these advantages, global pellet production reached 30 million tons in 2019, with Europe and Asia together accounting for approximately 75 percent of total demand (IEA 2020). According to the European Council of European Union (2021), demand for biomass has risen since the 2000s and is expected to continue increasing in response to a recent Renewable Energy Directive, in which the European Council called for a European Union–wide domestic greenhouse gases (GHG) reduction target of $\geq$55 percent below 2021 levels by 2030 (European Environment Agency 2021).

The European Union (EU) is the world's largest wood pellet consumer and importer, taking up 51 percent of the global wood pellet production (Sun and Niquidet 2017). In 2020, the biggest wood pellet consumers and importers within the EU were the United Kingdom, Italy, Sweden, Denmark, Germany, Belgium, and Holland (Jaganmohan 2021). The demand for wood pellets in Europe is primarily driven by the need for renewable energy sources to meet climate targets and support for bioenergy in the form of the

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Renewable Energy Directive and renewable energy sources (Thrän et al. 2019).

The United States is the largest producer of industrial roundwood in the world (Statista 2022). In response to increased global demand, the United States has drastically increased its production of wood pellets in the past two decades. The majority of production takes place in the South, specifically in states such as Georgia, Alabama, and Virginia (Dwivedi et al. 2011). The US wood pellet industry has a significant impact on both domestic consumption and exports. In terms of domestic consumption of wood pellets, most of the demand came from the residential sector for heating purposes. The Wood Pellet Association of Canada reported that the United States exported approximately 7 million tons of wood pellets in 2020. Most of US wood pellet production (85%) is exported, mainly to the EU, Japan, and South Korea; and in 2019, wood pellets from the United States accounted for >30 percent of the market share in the EU (Rodriguez Franco 2022). Canada was the second largest wood pellet exporter in the EU, accounting for about 8 percent of the market share (Statista 2022). As of 2020, the United States is the world's largest wood pellet producer and exporter (Statista 2022).

Previous studies examined either supply chain or carbon emissions of wood pellet production in context of renewable energy (Conrad et al. 2010, Sjlie et al. 2010, Atasoy and Atasoy 2020). For example, Condrad et al. (2010) examined the pellet supply chain in the southern region of the United States over the past two decades. They state that there have been inadequate consumer markets for timber as a result of expanded timber supply and high volume of export products. Sherman and Pelkki (2019) also focused on the supply side of the woody residuals and woody-fueled energy sources in northwestern Arkansas. Morrison and Golden (2017) compared the environmental implications of co-firing coal and wood pellets in the Southeastern United States. Their analysis results indicate co-firing with wood pellets could be a viable interim solution for the aging fleet of coal-fired power plants within the Southeastern United States, particularly if stricter emission regulations and renewable portfolio standards are implemented.

The objective of this paper is to study the regional excess supply of wood pellets from the United States. Despite the rapid growth of wood pellet production and trade in the past few decades, literature on the supply and demand of this new forest product is limited (Johnston et al. 2022). Because the majority of wood pellets from the United States have been exported (Statista 2022) and European countries remain the world's largest pellet importers, taking up more than approximately 50 percent of the global market, it is critical to examine the excess wood pellet supply from the United States and the potential impact of EU policy changes. Therefore, this study examines the EU Council Decision on 25 April 2002, which implemented various measures for the EU to reduce GHG emissions to comply with the Kyoto Protocol, and another decision made at the end of 2008 when the EU agreed on legally committed compulsory targets to reduce the GHG emission by 20 percent (The EU Renewable Energy Directive [European Commission 2009]).

Theoretical and Econometrical Methodology

The wood pellet industry in the United States is assumed to be competitive in this study for a couple of reasons. First, wood pellet production is a relatively low-tech industry, and the amount of capital needed for a wood pellet plant is smaller than for a sawmill or plywood mill. Second, the material used to produce wood pellets—wood residues and pulpwood—is plentiful in most parts of the United States, which has had more forest growth than it does drain from harvesting for many decades. In other words, the barrier to entry in wood pellet production is low. For example, in the South region of the United States (comprising the states of Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Virginia, Tennessee, Texas, and Oklahoma), there were 46 wood pellet producers in 2021. Thus, with many suppliers of raw materials and wood pellet producers, the wood pellet price variable is considered an exogeneous explanatory variable as in a competitive market (Biomass Magazine 2021).

In a competitive market, producers are profit maximizers (e.g., Reed et al. 2012, Schipfer et al. 2020). They try to achieve their goals with given input and output prices. Therefore, the primary form of a wood pellet producer's profit function can be expressed as follows:

$$\pi_{ijt}(P_{ijt}, w_{ijt}) = Max_{Q_{ijt}L_{ijt}}\left[P_{it}Q_{ijt} - W_{it}L_{ijt}\right] \quad (1)$$

where π is a profit function, P is the price of the wood pellet, Q is the exported wood pellet, W is a vector of input prices, and L is the vector of inputs. Also, in Equation 1, j is the jth firm, i is the ith region, and t is years. The profit function is assumed as convex in prices P and W; therefore, in application of Hotelling's Lemma (Hotelling 1932), the supply curve can be derived by differentiating the profit function with respect to the market prices.

$$\frac{\partial \pi_{ijt}}{\partial P_{it}} = Q_{ij}(P_{it}, W_{it}) \quad (2)$$

Assuming all N firms in a region have a similar production function, we can aggregate all N individual firms' supply function to find the supply function of the region i. Thus, we can define the wood pellet supply in region i as a function of wood pellet price and the prices of the inputs, including energy, capital, labor, and materials (represented in this study by sawmills-wood chips, wood waste, branch, sawdust):

$$Q_i(P_{it}, W_{it}) = \sum_{j=1}^{N} Q_{ij}(P_{it}, W_{it}) \quad (3)$$

The methods used to estimate the supply function of forest products include ordinary least squares (OLS), 2 stage least square (2SLS), or SUR. The SUR model is used for many regional-supplies function-estimation studies in the applied economics literature (Nagubadi et al. 2004, Alfranca et al. 2014).

In the literature, comparison of SUR and full-information maximum likelihood estimation (FIML) of a simultaneous equation model have been examined. Many studies on the performance of the SUR and the FIML methods for estimating a simultaneous equation model show that the SUR method is more efficient and robust than the FIML method (Prucha 1985, Zhao et al. 2022). Ando and Zellner (2010) examined into SUR equations and temporal aggregation and conclude that the SUR method can be used to estimate a dynamic simultaneous equation model and that it is more efficient than the OLS method when the error terms are correlated over time. Henningsen and Hamann (2008) evaluated both the SUR and 2SLS estimation procedures. They conclude that the SUR method is more efficient than the 2SLS method when the error terms are correlated across equations. Therefore, this study uses the SUR model (Zellner 1962, Dwivedi and Srivastava 1978 [OLS model is also applied in the data set; however, it was not included in this research for brevity of the study. OLS results can be requested from the authors]). This model has some advantages: the estimation is more efficient because the correlation of the terms of error increases and provides lower correlation between explanatory variables. SUR is considered joint modelling because it allows an estimation of multiple models at the same time (Majumdar et al. 2010). The empirical regional excess supply function is specified as follows:

$$Q^S_{R,t} = f(P_{R,t}, MC_t, EC_t, i_t, HW_t, D_{1,t}, D_{2,t}, T) \qquad (4)$$

where P is the own price of pellet products, MC is the material cost (of wood), and i is the interest rate. HW is the hourly wages, D_1 and D_2 are two dummy variables representing two policy changes in the EU, and T is a trend variable. In the profit maximization equation, i shows region; however, in Equation 4, i is replaced by R, which represents the North (Northeast and Northcentral), West, and East regions of the United States.

Data

Table 1 presents the data used in our econometrical estimation of the US export volume, including variable definitions and data sources. The wood pellet export data were obtained from the United States International Trade Commission (USITC) DataWeb (https://dataweb.usitc.gov/). It is an annual data set showing the export volume of wood pellets by port, and regional excess supply is therefore an aggregation of all export volumes from all ports in the region. This is Harmonized Trade Schedule (HTS-6) -level data in terms of commodities. Note that the descriptions of wood pellet data differ between 1996 and 2011 and afterward. Before 2011 (1996 was the earliest available data set), wood pellets (item '440130' under HTS-6) are included in the commodity defined as ''sawdust and wood waste and scrap, whether or not agglomerated in logs, briquettes, pellets or similar forms.'' Afterward, a new stand-alone HTS code '440131' has been introduced for wood pellets in the USITC system.

Initially, the United States was divided into four regions to calculate regional excess supply: West (WE), South (SO), North Central (NC), and Northeast (NE). However, the export volume from NC and NE has been relatively small. Therefore, we combined these two regions as one: North (NO). So we have three regions—NO, WE, and SO. USITC reports both the actual total value of the wood pellet and the total unit of quantity of the product. The price of the exported wood pellets is obtained by dividing the total value by total quantity. The price and quantity of the exported wood pellet are given by US dollars/metric tons (Mt) and Mt (Table 1).

All input prices were obtained from Producers Prices Index (PPI), which was released by the Bureau of Labor Statistics (2022). Energy cost is hourly electric cost by kilowatt per hour measured by PPI. The interest rate is an annual average prime rate derived from the JPMorgan Chase Historical Prime Rate (JPMorgan Chase & Co. 2022).

Many commentators believe that the rise of wood pellet imports in the EU is related to its energy policy. Thus, it is important to examine the EU policy changes (Bioenergy Europe 2022, Statista 2022). In the early 2000s, the EU set a goal of reducing GHG emissions and complying with the Kyoto Protocol to the United Nations Framework Convention on Climate Change. It issued various measures via Council Decision of 25 April 2002, 2002/358/EC (The European Union Council Decision of 25 April 2002 concerning the approval, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32002D0358), which we designate as Policy 1 in the current study (Dummy variable, D_1). Similarly, Policy 2 (Dummy variable, D_2) represents the EU Renewable Energy Directive 2009/28/EC (The European Parliament and of the Council of 23 April 2009, https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex%3A32009L0028), which committed the EU to legally compulsory targets for reducing GHG emissions by 20 percent by 2020.

Results

For examination of regional excess supply analysis in the United States from 1996 to 2021, we used the Statistical Analysis of Software (SAS 9.5) for all procedures. Table 2 presents descriptive statistics of the variables used in this study. The mean value of excess supply in the South is the largest among of the three regions. Figure 1 shows the logarithmic value of the excess supply of the three regions. Figure 2 shows that actual value of excess wood pellet supply in the South increased rapidly after 2011. These two

Table 1.—Variable definitions and data sources used in our econometrical estimation of the US export volume.

Variables	Description	Data sources
$Q_{R,t}$	Excess supply, wood pellet export by year and region as Metric tons (Mt)	United States International Trade Commission (USITC) DataWeb
$P_{R,t}$	Pellet prices (US dollars [USD]/Mt) by region and year	United States International Trade Commission DataWeb
MC_t	Material cost of sawmills-wood chips, excluding field chips (USD/Mt) by year	Producers Prices Index (PPI)
EC_t	Hourly electric cost for industry by kw/h per year	Producers Prices Index (PPI)
HW_t	Average hourly earnings in the industry by USD and year	Bureau of Labor Statistics
i_t	Yearly average prime interest rate (%)	JPMorgan Chase Historical Prime rate
D_{1t}	EU Policy 1, $D_{1t} = 1$ if $t \geq 2002$; 0 otherwise	EU Council Decision on 25 April 2002, 2002/358/EC
D_{2t}	EU Policy 2 $D_{2t} = 1$ if $t \geq 2009$; 0 otherwise	The EU Renewable Energy Directive 2009/28/EC
R	Regions = North (NO), West (WE), and South (SO)	
t	Time; from 1996 to 2021	

Table 2.—Descriptive statistics values.

Variable	Mean	SD	Min.	Max.
Q_{SO}	2,028,230.01	270,188.01	6,501.64	7,480,690.02
Q_{NO}	16,764.46	7,787.69	4,988.15	43,805.75
Q_{WE}	13,996.27	9,592.69	3,357.27	55,044.17
P_{NO}	261.65	113.90	151.29	396.54
P_{SO}	278.42	128.46	123.37	421.51
P_{WE}	291.25	125.37	164.31	407.59
MC	46.02	25.43	22.90	81.51
EC	6.06	1.01	4.48	7.28
HW	15.11	2.61	11.31	20.90
i	5.27	2.023	3.25	8.75

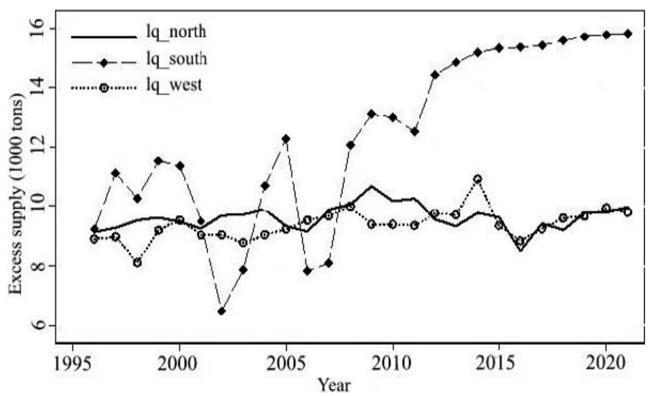

Figure 1.—Logarithmic value of regional excess wood pellet supply in the United States from 1996 to 2021.

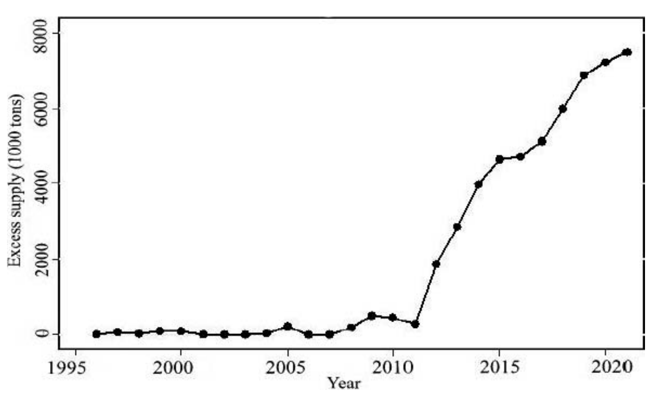

Figure 2.—Excess wood pellet supply of the South Region of the United States from 1996 to 2021.

figures indicate that volume of the excess wood pellet supply in the South region is almost twice as large as the total excess supply in the other regions.

We had a time series data set, so it was important to investigate the properties of the variables to ensure stationary of the estimated parameters. Thus, we used the Augmented Dickey Fuller method to test stationarity of each variable Akaike (AIC) Information Criteria to select our model. As Table 3 shows, the excess supply in the North and West and price of the pellet, were stationary in levels. All other variables are nonstationary in levels, nor are they integrated of order one. Consequently, the difference of each variable is taken to make them stationary. Difference

Table 3.—Augmented Dickey Fuller (ADF) Unit Root Test results.

Variables	ADF[a]	Probability values	Integrated[b]
lq_SO	−1.417	0.574	I(1)
dlq_SO	−4.579***	0.000	I(0)
lq_WE	−3.106***	0.026	I(0)
lq_NO	−3.143***	0.023	I(0)
P	−3.549***	0.006	I(0)
MC	−1.308	0.625	I(1)
Δ(MC)	−4.878***	0.000	I(0)
EC	−0.886	0.792	I(1)
Δ(EC)	−4.024***	0.001	I(0)
HW	2.168	0.998	I(1)
Δ(HW)	−3.133***	0.024	I(0)
i	−1.657	0.453	I(1)
Δ(i)	−3.299***	0.014	I(0)

[a] *** $P < 0.01$, ** $P < 0.05$, * $P < 0.1$.
[b] Numbers in parentheses indicate optimal lag length suggested by the Akaike Information Criterion (AIC).

of interest rate, material cost, and energy cost is thus taken, after which each series becomes stationary.

For all the variables that become stationary after taking their difference, we employed the difference variable as an independent variable in our model. We also applied diagnostic testing for multicollinearity using the Variance Inflating factor (VIF); since the VIF is small for each variable in the study, so our view is that there is no issue of multicollinearity in the model. Thirdly, we checked for autocorrelation using the Durbin-Watson (DW) statistic and for possible presence of heteroscedasticity using Breusch-Pagan test. The value of the DW test is approximately 2, so we can state that there is no issue with autocorrelation for the three regions. In addition, the probability value of the Breusch-Pagan test is >0.05, so there is not any problem of heteroscedasticity. After these diagnostic tests, we used the

Table 4.—Seemingly Unrelated Regression (SUR) results of regional excess wood pellet supply, 1996 to 2021.[a]

Variables	Ln (south)	Ln (west)	Ln (north)
Constant	8.476***	8.971***	9.780***
	(0.452)	(0.313)	(0.259)
Log(P)	0.1467***	0.1511*	0.1395***
	(0.0552)	(0.0906)	(0.0681)
HW	−0.0411*	−0.396	−0.0555**
	(0.0290)	(0.270)	(0.0224)
i	−0.0217**	−0.0317*	−0.0610***
	(0.0152)	(0.0211)	(0.0279)
MC	−0.0289***	−0.0540*	−0.0507**
	(0.0078)	(0.0395)	(0.0325)
EC	−0.0541*	−0.0723**	−0.0559**
	(0.0312)	(0.0367)	(0.0304)
D_1	−0.0304*	−0.272	−0.169
	(0.0198)	(0.329)	(0.273)
D_2	1.223***	0.669***	0.427*
	(0.445)	(0.311)	(0.258)
T	0.076**	0.0311	−0.00410
	(0.0058)	(0.0280)	(0.0232)
Observations	25	25	25
R^2	0.976	0.697	0.681

[a] SEs in parentheses. *** $P < 0.01$, ** $P < 0.05$, * $P < 0.1$.

SUR model to estimate excess wood pellet supply in the three regions (Table 4).

Unlike the excess supply in the North and West, the excess supply quantity in the South region is not stationary at the level, but stationary at the first differences. Yet, and as noted earlier, the pellet price variable is stationary at the level. This kind of estimation will not be straightforward for calculating elasticity. However, even if endogeneity is our concern and given that the wood pellet market in the South is considered a competitive market, the price elasticity can therefore be calculated either with variables either at the level or in the first difference. Here, we decided to run the quantity variable without taking a first difference.

There are some other econometric solutions to calculate the price elasticity if endogeneity is a concern; for instance, 2SLS can be used as aforementioned in the Methods section. Another option is to use variance analysis ratio (VAR) to estimate the dynamic elasticity using the impulse-response function estimates. Static elasticity can be found in a cointegrating vector estimation if there is cointegration. As wood pellets in the South region of the United States have been considered a competitive application of 2SLS or dynamic elasticity, estimations are not necessary (Rotemberg and Woodford 1995, Duden et al. 2017).

The estimates for excess supply in the South region show that all variables are statistically significant. Price elasticity of wood pellets is approximately 0.14 and it has positive impact on excess supply, as expected. The interest rate, material cost, and hourly wage variables have negative impacts, while Policy 2 has a positive and statistically significant effect on the excess supply. The South region shows the highest (0.97) R^2 level, and thus has the highest explanatory power among the regions, which is expected considering the Southern region drives wood pellet supply in terms of production volume in the United States. Contrary to our expectations, Policy 1 has a small negative effect on excess wood pellet supply in the South.

The excess supply estimates in the West show that only two variables are not statistically significant. The significant variables in the West region include hourly wage, interest rate, and Policy 2, which affected excess supply during the study period. The coefficients of interest rate and hourly wage have a negative effect while Policy 2 has positive and statistically significant effect on excess supply. The highest coefficient for the Policy 2 dummy is in the South region, which is significant at the 0.01 level. Interestingly, the coefficient of D_2 is approximately 50 percent smaller in the West and three times smaller in the North in comparison with the South.

In the West and North regions, prices and excess supply are stationary at the level and taking the logarithmic value; so 0.15 for WE and 0.13 for NO represent their respective regional price elasticity for excess wood pellet supply. Both regional excess supplies have been positively influenced by price. Unlike the South, the first dummy D_1 standing for Policy 1 does not have a statistically significant impact on either the West or North regions' excess supply.

Discussion and Conclusions

In this paper, we estimated the regional excess supply of wood pellets in the United States from 1996 to 2021. The United States is the largest producer and exporter of wood pellets (Gu et al. 2019), so this paper contributes to the woody biomass and energy economics literature.

The SUR estimation shows that an increase in wood pellet prices leads to increased excess supply for all regions. This means that the short-term supply of the product is inelastic because the increase in production capacity is limited. Hourly labor wages have minor impact on the South and North regions, whereas they have no significant influence on the West region of the United States; this shows that wood pellet production is relatively less labor-intensive, and more machinery-produced.

Our results show the significance of economy and policy matters due to the effect of the two European clean energy policies on the US export supply of wood pellet. In the early 2000s, the European Union set a goal to reduce GHG emissions and comply with the Kyoto Protocol (2002/358/EC). The first EU policy was not thoroughly implemented for a couple of reasons and failed for some reasons stated by Grunewald and Martinez-Zarzoso (2016). We found that Policy 1 does not have statistically significant effect on any of the three regions of our study. The second policy was one of the recent clean energy targets (EU Renewable Energy Directive 2009/28/EC) to reduce GHG emission by 20 percent by 2020. Our results show statistically significant and positive influence of this policy on the three regions' excess wood pellet supply. The results are also consistent with the effectiveness of the policy—European policies on climate and energy report in 2014 showed that the European Union already achieved its 2020 goal for reduction of GHG emissions (European Environment Agency 2021).

The analysis results have some practical, policy, and sustainability implications. First, in July 2021, the EU Council established a new EU-wide domestic GHG reduction target of $\geq$55 percent below its current level (2.54 billion metric tons) by 2030. Based on our estimates, this policy will be effective and thus EU demand for wood pellets will increase. Second, the US government has provided an incentive since January 2021—a new Wood and Pellet Heater Investment Tax Credit—to encourage wood pellet production, under which consumers buying wood or pellet stoves, or larger residential biomass heating systems, can claim a 26 percent tax credit that is uncapped and based on full cost (purchase and installation) of the unit according to the Internal Revenue Service Section 25(D) (Pellet Fuel Institute 2022). This policy is likely to increase US supply of wood pellets, raising concerns on the sustainability of wood pellet production and material prices, especially in the Southern United States (Parajuli 2021, Johnston et al. 2022). Finally, our results show that excess supply of wood pellets in the United States is negatively affected by interest rates and energy costs, which are rising. Therefore, it is unlikely that the excess supply of wood pellets in the South will continue to rise at the rate shown in Figure 2 after 2011.

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