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SupplyChip: Facilitating the Supply of Energy Wood from Forest to Major Heat User

Teagasc
Agriculture and Food Development Authority

COFORD
National Council for Forest Research & Development
An Chomhairle Náisiúnta um Thaighde agus Forbairt Foraoise

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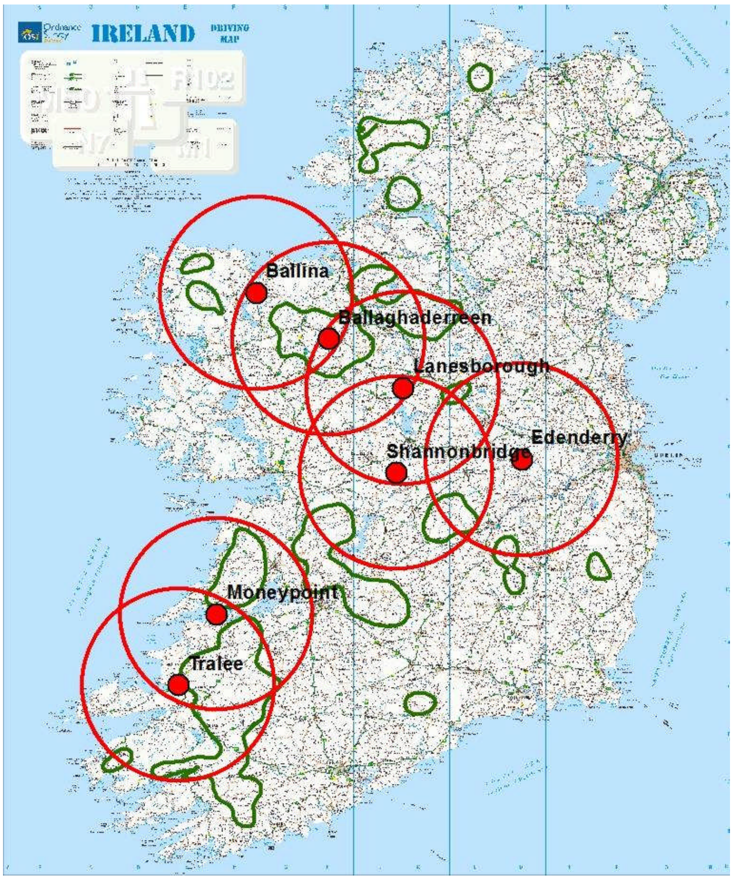

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CHP	Combined Heat and Power
DEM	Digital Elevation Model
FC	Forestry Commission
FIPS	Forest Information and Planning System
GIS	Geographic Information System
GYC	General Yield Class
OSi	Ordnance Survey of Ireland
LUT	Land Use Type
MMAI	Maximum Mean Annual Increment
MW	Mega Watts
NFI	National Forest Inventory
PCRW	Post Consumer Recovered Wood
PGA	Private Grant Aided
PNGA	Private Non-Grant Aided
RES	Renewable Energy Source
ROI	Republic of Ireland
SEAI	Sustainable Energy Authority of Ireland
SRC	Short Rotation Coppice
toe	Tonnes of Oil Equivalent
TJ	Tetra Joule
WP	Western Package

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Acknowledgements

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Executive Summary

Background: The private sector now accounts for 47% of the total forest area with the majority of plantations being established within the past twenty years. A COFORD-funded private sector geospatial forecast based on the most complete and up to date information was published in 2009 (Phillips *et al*. 2009) and provided volume forecast estimates at national, regional, county and catchment levels. It identified a number of data limitations including the lack of information on access, stocking, management intentions and productivity. The All Ireland forecast (Phillips, 2011) combined forecast data from (a) the private sector geospatial forecast (Phillips et al. 2009) (b) Coillte's Forecast 2011, (c) Northern Ireland Forest Service (NIFS) forecast of softwood availability and (d) potential softwood availability from the private sector in Northern Ireland. It introduced the term "net realisable volume" to better estimate the roundwood volume available to end-users by taking into account volume losses during harvesting and also provided an estimate of wood fibre potentially available for wood energy.

The Renewable Energy Directive (2009/28/EC) has set ambitious targets for Ireland – that by 2020 at least 16% of all energy consumed is from renewables. The All-Ireland Roundwood Demand Forecast 2011 - 2020 (COFORD Roundwood Demand Group 2011) estimates that the annual demand for roundwood will increase to 6.04 million m^3 by 2020, including an estimated demand of 3.08 million m^3 for wood biomass for energy purposes leaving a shortfall in supply of circa 1 million m^3 by 2020 and almost all of this in the forest-based biomass category.

Against this background of increasingly demanding national targets for renewable energy, increasing demand for wood fibre and a relatively flat roundwood forecast from state owned forests, any increase in future supply is dependent on privately owned forests. Future forecasts if they are to meet the needs of industry must provide detailed estimates of wood energy and catchment based potential supply volumes bearing in mind the issues of accessibility and site productivity.

The **SupplyChip** project is timely in that it not only provides forecast estimates of energy wood assortment but also addresses the deficiencies associated with previous private sector forecasts as for example access and the basis for estimation productive capacity (yield class). The project objectives are to:

- **a)** Quantify the likely breakdown by volume of wood energy assortments within an identified cluster area i.e. Ballaghaderreen, County Roscommon;
- **b)** Examine the roading infrastructure - national, county and within forest networks that will facilitate harvesting; and
- **c)** Provide a wood energy flow to potential users (co-fired power plants, CHP plants and industry) through the ranking of plantations based on roading infrastructure, wood energy potential and haulage distance to end users.

The SupplyChip project utilises the Ballaghaderreen cluster (3,276 private plantations with circa 11,500 ha) and expands on the data already collected but in particular on accessibility and the basis for determining the future management regime of the forest areas. It differs from the CLUSTER project in that it is not based on sample data, rather it utilises the information from each of the forest areas within the cluster.

Methodology: The methodology comprised of three elements - (a) updating and improving the dataset, (b) field validation of data and (c) developing a forecast model. The starting point was the CLUSTER dataset which combined the FIPS98 and the Premiums dataset extracted from IFORIS to form one master database. Extensive spatial analysis and quality control procedures were used to eliminate duplicates and to realign external boundaries with features from the orthophotos.

The initial phase of aerial photography analysis involved updating the existing spatial database. Each plantation was visually assessed and its attributes noted in the GIS. The database was updated to include information on whether the plantation was visible in the 2005 orthophotos, and its development stage (Ground preparation, Pre-thicket, Thicket or Pole). The underlying Ordnance Survey map ornament, and whether the land was enclosed or unenclosed were also assessed and each site was classified into four land-use types according to O'Carroll's (1975) site fertility classification. All plantations which were included in the input datasets were checked against the 2005 aerial photography and the database updated accordingly. Neither of the input datasets contained any information about unproductive areas within plantations. To address this, each stand was visually assessed using aerial photographs to determine the percentage productive area.

Each of the 3,276 stands was assessed for accessibility using aerial photos and road maps and classified as being either (a) not adjacent, (b) adjacent, (c) within 50m of a third class road or (d) within 50m of a fourth class road. Based on this, 88% of the study area was classified as being reasonably accessible to the public road network i.e. within 50m of a third or fourth class road, with the remaining 12% were classed as inaccessible. The good level of accessibility is attributable in part to the concentration of plantations within the cluster area. The presence of internal forest roads was also recorded and whether the stand had been thinned.

SupplyChip concentrated on improving the basic dataset by appending additional spatial data to each of the 3,276 forest stands. Some of these data were necessary to assign potential productivity (yield class) and to derive the thinning potential of individual stands, while others allowed for a more comprehensive information base for future analysis and interrogation.

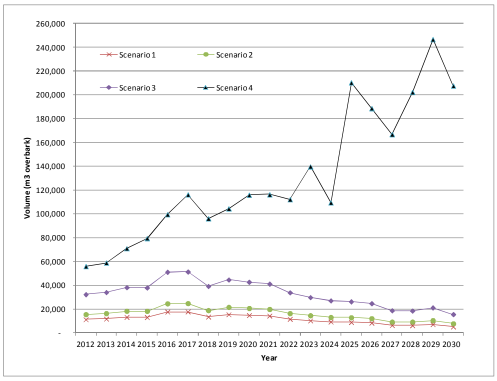
Yield class for Sitka spruce was calculated using the *Forecast Model* described by Farrelly *et al*., (2011) (soil, parent material, fertility class and wind speed). To estimate forest productivity for other species, a look-up table similar to that used in the 2009 private forecast was used. Where Sitka spruce was the first species within the stand, the average weighted yield class was 23.5 with a range from 12 to 30.

In order to evaluate the potential of each forest stand as a source of thinnings for wood energy, a decision tree based on area, public road access and ground conditions was developed and the suitability of each site for thinning was evaluated using specific criteria under these headings and a thinning and rotation regime / classification then applied to each stand. The classifications used were (a) standard thin, (b) reduced thin and (c) no thin. Standard rotation lengths were determined based on the findings from a previous economic analysis (Phillips, 2008) with the price data updated. The reduced rotation length for conifers was based on the age required to reach a top height of 21m.

Two field validation surveys were undertaken. The first survey focussed on ground truthing to correlate the visual assessment from the aerial photography analysis with actual conditions on the ground. The second concentrated on validating the assessment of productive area, plantation access and also examined the relationship between plantation size and thinning status.

Forecasting Rules and Assumptions: The Forestry Commission (FC) yield models for forest management (Forestry Commission, 1981) were used to forecast future volume production. FC assortment tables were used to allocate volumes to the four size assortment categories. (Matthews and Mackie, 2006) - (1) 6cm to tip, (2) 7cm to 13cm, (3) 14cm - 19cm and (4) 20cm and greater. Attrition is the loss in productive capacity due to the incidence over time of windthrow and disease. A default attrition factor of 5% was used. To allow the forecast to estimate energy wood volumes post harvesting at roadside, it was necessary to determine the extent of harvest loss. The private sector forecast had used a series of default values. These values were adjusted downward to reflect that thinnings volumes were being directed at energy markets. Where there were more than four species in a stand, the area was allocated proportionally between the first four species.

Scenarios and Scenario Analysis: Roundwood is a flexible raw material in that it can be directed to a number of potential markets. Thus four possible wood energy supply scenarios were identified: (a) Scenario **S1**: 40% of the 7-13cm assortment goes to wood energy; (b) Scenario **S2**: 40% of the 7-13cm and all tree tops (tip -6cm) go to wood energy; (c) Scenario **S3**: 100% of the 7-13cm and all tree tops go to wood energy; and (d) Scenario **S4**: 100% of all size assortments go to wood energy. This range of scenarios recognises that energy wood has to compete with existing markets for supply.

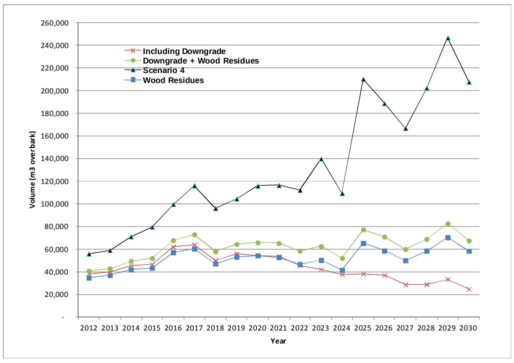


Under **S1**, wood energy potential is forecast to increase from 11,000 m³ to reach a maximum of 18,000 m³ per annum in 2017, then decline gradually to 14,200 m³ in 2021 and thereafter to more rapidly to 5,100 m³ in 2030. Under **S2**, the inclusion of additional material from the tree top assortment increases the estimated forecast wood energy supply to 25,000 m³ by 2017. Thereafter the forecast supply follows a similar pattern to **S1**. Under **S3** there is a significant increase in the forecast energy wood volumes and supply increases from 32,000 m³ in 2012 to reach a peak of 45,000m³ in 2019. Thereafter forecast supply decreases gradually to 30,000 m³ by 2023 and then more rapidly to 16,500m³ by 2030. Under **S4**, this assumes that all volumes will go to energy wood, the forecast supply increases from 56,000 m3 in 2012 to reach a peak of 247,000 m3 in 2029, declining to 208,000 m3 in the final year of the forecast. There are a number of peaks and troughs in the forecast supply, reflecting significant clearfell areas and the age class distribution of plantations within the cluster area.

Suitability of Supply to End Users: The table shows the suitability of supply to the needs of a range of potential end users from small local facilities e.g. schools or public buildings to industrial scale co-firing.

Scenario Analysis - Potential End Users and Demand Levels:

User	Potential Users	Demand	Likely Scenario	Comments
Local Level	Town based facilities (nursing homes, etc)	<20,000 m^3	S1	Sufficient available wood energy under scenario for 10 -20 local facilities
Medium scale	Ballaghaderreen (12 MW steam boiler)	35,000-40,000 m^3	S3	Only scenario 3 offers a realistic supply, likely will have to rely on additional sawmill residues with scenario 2
Industrial scale	Lanesborough (co-firing)	100,000 m^3	S4 S1-3 with increase of catchment area to 40,000 ha	Only scenario 4 offers a realistic supply, would have to rely on additional volume assortments or increase catchment area.



Sensitivity Analysis: Three possibilities were examined. The first was where 30% of the volume in the 14-19 cm assortment was downgraded and made available for energy wood. The second was where half of the estimated wood residues from the processing of the larger assortments, having made allowance for the downgrade, were made available for wood energy. The third was a combination of the first and second. Including downgrade has the effect of increasing the level of supply which peaks at 64,000 m^3 in 2017 and then decreases to 30,000 m^3 towards the end of the forecast period. This average level of supply is sufficient to more than meet 100% of the requirements for a 12MW facility with the proviso requiring the purchase of some additional material in the last five year period. The rate of decrease in supply exhibited under scenarios S1-S3 after 2020 has been lessened and a more sustainable supply is possible. When 50% of the wood residues are made available, then not only is the level of supply increased but also and perhaps more importantly the shape of the supply curve with sufficient volume to meet a 12MW facility and a proportion of anticipated local market needs. When the combined impact of downgrade and wood residues are considered, the supply is capable of meeting local market needs and one major 12 MW user.

Discussion: Good decisions require good information. The SupplyChip forecast uses local stand information and improved spatial data to generate a local forecast for wood energy. This is a significant step forward as up until now, catchment or regional forecasts for the private sector relied on inferred data to a greater or lesser extent. Thus while the private sector forecast (Phillips et al, 2009) has the facility to generate a forecast for a 30k or 50k catchment around Ballaghaderreen, it uses high level assumptions which while they hold up nationally, need to be treated with caution at the catchment level.

The benefits of using local information to generate local supply forecasts whether this be for a local producer group or for a potential end user or group of end users has implications for the COFORD working group on forest management planning. It will be important that any revised format for the management plan has the capacity to include the type of information that can input to the generation of robust local forecasts.

Conclusion: The methodology enabled the development of a robust and accurate dataset which was further enhanced through the appending of a wide range of spatial data. The estimation of site productivity (yield class) using the *Forecast Model* described by Farrelly *et al*., (2011) provided a more reliable basis than previous approaches. The methodology, building on the results of the Cluster project, demonstrates that it is possible to develop forecasts based on individual stand data that are reliable and suitable as a basis to determine future wood energy flows. The methodology developed is capable of being replicated in each of the other 15 identified clusters and as such has all Ireland application.

Finally the project demonstrates that identified cluster areas of private plantations are capable of supplying sustainable levels of wood energy flows to a variety of end users.

Background

Private Forest Estate

The national forest estate has increased from just less than 90,000 ha in 1928 to over 750,000 ha in 2012, an area which represents 11% of the land of the country. Approximately 352,000 ha (47%) is privately owned while the remaining 53% is publicly-owned, primarily by the State owned company, Coillte Teoranta.

Up to the 1980s almost all afforestation was undertaken by the State. With the introduction of the State/EU funded forestry grant and annual payment / premium schemes private landowners, mainly farmers, but also including pension, investment and corporate funds began to plant significant amounts of forest. Between 1989 and 2011, a total of 21,992 private grant aided plantations were established with a total area of 205,859 ha[1].

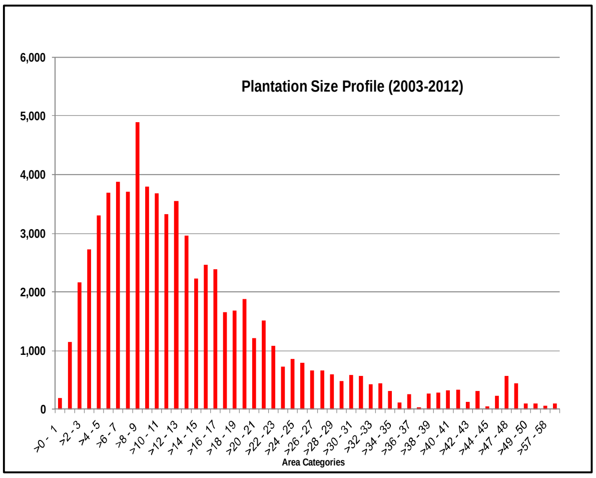


Figure 1: Private Plantation Size Distribution

The private forest estate essentially comprises of two distinct forest types, the older non grant aided forests where broadleaved species and old woodland dominate referred to as private (other) in the National Forest Inventory (NFI) and the younger grant aided plantations where conifer species dominate. Although Sitka spruce (*Picea sitchensis*) has been the main species planted over the past twenty years, broadleaf species, in particular ash, alder and oak now account for more than 30% of annual planting.

The average plantation size for grant aided forests is 9.36 ha, although this has decreased with more recent planting to 8.13 ha between 2003 and 2010. In the 1990s, a significant proportion of private afforestation was "whole farm" planting, whereas in recent years, planting has been to a considerable degree taken place within individual agricultural holdings. This fragmentation within the private forest estate has implications for subsequent management and harvesting activities.

Forecasting Private Sector Volumes

Since the publication in 2001 of the forecast of roundwood production from the forests of Ireland (Gallagher and O'Carroll 2001) there has been a downturn in private planting coupled with major changes in species composition in the Republic of Ireland (ROI). More importantly, there has been a significant advance in the capacity to forecast timber volumes from the private sector and in the quality of the datasets used to forecast these volumes. A COFORD-funded private sector geospatial forecast was published in 2009 (Phillips *et al*. 2009) which provided volume forecast estimates at national, regional, county and catchment levels. The main strengths of the forecast were that it was based on spatial data and on the most complete and up-to-date information that was available on private forests. This included species data which facilitated the forecasting of volume production by species group, which was missing in previous private sector forecasts. The spatial basis enabled the production of catchment and other scenario-based forecasts. Such forecasts have increasing importance in planning the location of new wood using enterprises related to energy and other end uses. However the private sector geospatial forecast recognised a number of limitations which need to be addressed in any future forecast including primarily:-

a) Lack of information on accessibility of private plantations;

[1] Fergus Moore, Forest Service, presentation to COFORD Support Group on Forest Management Planning, 28th June 2012.

b) Limited information on stocking in privately owned plantations;
c) Little information on the management intentions of private forest owners; and
d) The productivity estimate for each plantation was based on a sample from the Coillte forest estate which may not be fully representative of private forests.

The forecast expressed the view that most of these shortcomings could be overcome. In this regard, accessibility could be interpreted based on orthophotos, ordnance survey Ireland (OSi) spatial datasets on road networks and proximity of adjoining plantations, while site productivity could be based on the Teagasc model for Sitka spruce (Farrelly et al, 2009) which should improve the reliability of production forecasting.

The All Ireland forecast (Phillips, 2011) combined forecast data from (a) the private sector geospatial forecast (Phillips et al. 2009) (b) Coillte's Forecast 2011, (c) Northern Ireland Forest Service (NIFS) forecast of softwood availability and (d) potential softwood availability from the private sector in Northern Ireland. It introduced the term "net realisable volume" in an attempt to better estimate the roundwood volume available to end-users by taking into account volume losses during harvesting. In the forecast volumes for the private sector were adjusted to exclude thinnings from small plots and those plantations with a potential uneconomic forest roading requirement, based on a high level geospatial analysis. These areas were assigned a no-thinning regime and assumed to be harvestable at time of clearfell. This resulted in a reduction in thinning volumes and an increase in clearfell volumes over the forecast period. The All Ireland forecast estimates that by 2028 the production capacity of Ireland's forests will almost double to 7 million m^3, from the current 3.79 million m^3. Almost all of the increase in supply is set to come from privately-owned forests in the Republic and based on this there is considerable scope to expand wood energy production. This is in addition to supplies for sawmilling and board manufacture.

The forest processing and emerging wood energy sectors require forecast volumes at an all-Ireland and regional / catchment level to underpin any investment decisions. There are now increasing competing demands for the smaller sized timber volume assortments which traditionally were used in the manufacture of wood panels and fencing materials and an increasing demand for local area forecasts to facilitate investment decisions on new or expanded production facilities.

Policy Drivers and Use of Woody Biomass

The Renewable Energy Directive (2009/28/EC) has set ambitious targets for Ireland – that by 2020 at least 16% of all energy consumed in the state is from renewable sources. The overall 16% target is further broken down into three renewable energy sectors - RES-T (10%), RES-H (12%) and RES-E (40%) targets (RES-E, RES-H and RES-T refer to electricity, heat and transport fuels derived from renewable energy sources). The Sustainable Energy Authority of Ireland (SEAI) in their recent analysis (SEAI, 2012) estimate that 1,000 ktoe[2] of bioenergy is required to meet domestic targets for renewable energy in 2020. This is made up of 370 ktoe for transport, 475 ktoe for heat and 155 ktoe for electricity. However the SEAI report concludes that even at the highest price point of 1,590 €/toe this would not bring enough domestic resources into production to meet the RES-T target. The analysis concludes that should current prices levels for bioenergy resources prevail into the future, it is likely that much of the available domestic potential will not be developed. A 50% increase in price, particularly for woody biomass resources, could see a significant increase in the quantity of domestic bioenergy resources consumed. For the resources examined, a 250% increase could see almost all of the available domestic resource potential being brought into production with the potential for the expansion of short rotation coppice (SRC) willow and miscanthus contributing most.

In 2010, 34% of the roundwood harvested in the Republic of Ireland was used for the production of biomass energy (O'Driscoll and Knaggs 2012). The Irish market for firewood has grown by 35% over the period 2006-2010 and in 2010 some 199,000 m^3 of firewood was sold in Ireland to a value of €28.80 million (O'Driscoll and Knaggs 2012). This harvest level is significantly above that which had been estimated for previous years and

[2] tonne oil equivalent (toe). 1 toe = 11.63 MWH or 41.868 GJ.

shows that the Irish firewood market is providing a steady and a growing market for first thinnings. Concurrent with this increase in firewood, since 2006, the use of wood biomass energy in Ireland has resulted in an estimated greenhouse gas emission saving of 2.03 million tonnes of carbon dioxide (CO_2).

The use of forest-based biomass for energy production is dominated by the forest products sector, which uses it for process drying and for energy purposes. Since 2007, the use of forest-based biomass for energy production by commercial and domestic users has risen considerably (Table 1). Between 2005 and 2009, the domestic use of forest-based biomass grew by 18% per annum. The output of the forest-based biomass energy sector is shown in Table 2.

Table 1: Use of Forest Based Biomass for Energy Production (O'Driscoll and Knaggs, 2012)

Category	**End use**	**2008**	**2009**	**2010**
		000 m^3 overbark		
Firewood	Domestic heating	171	184	199
Roundwood chipped in forest	Commercial heating	63	53	39
Short rotation coppice (SRC)	Commercial heating	1	4	1
Wood pellets & briquettes	Domestic /commercial heating	82	110	121
Charcoal	Domestic use	2	2	2
Wood biomass energy use by the energy & forest products industry	Process drying/heating / combined heat & power	384	438	554
	Total	**703**	**791**	**916**
	Percentage forest industry use	**55%**	**55%**	**60%**

Table 2: Output of Forest Based Biomass Energy Sector (O'Driscoll and Knaggs, 2012)

	Unit	**2008**	**2009**	**2010**
		Output		
Heat	TJ	4,857	5,273	6,306
Electricity	TJ	112	240	372
	Total	**4,969**	**5,513**	**6,678**
	CO_2 abated (000 tonnes)	380	422	511

The All-Ireland Roundwood Production Forecast 2011 – 2028 (Phillips 2011) estimates that the supply of forest-based biomass has the potential to increase by up to 50%, or 1.5 million m^3 by 2020. The report notes: '*The total is not an estimate of new or additional volume available for wood energy over and above current usage. Wood energy will have to compete with other end uses for the volumes indicated*.' There is potential to increase the level of supply of forest-based biomass in the period up to 2020 by:

1. Harvesting occurring in a higher proportion of forests that are due for thinning,
2. Removing larger amounts of biomass in thinning by using whole-tree harvesting systems (Kent et al. 2011), and
3. Removing harvesting residues and stumps from selected clearfell sites (Kent 2012).

The All-Ireland Roundwood Demand Forecast 2011 - 2020 (COFORD Roundwood Demand Group 2011) estimates that the annual demand for roundwood will increase to an estimated 6.04 million m^3 by 2020, including an estimated demand of 3.08 million m^3 of wood biomass for energy purposes. The estimated shortfall in supply of roundwood is around 1 million m^3 by 2020, mainly in the Republic of Ireland and almost all in the forest-based biomass category. The shortfall could be partly addressed by recovery of harvesting residues from suitable clearfell sites, and from increased fibre recovery from first and subsequent thinning. Supply could be increased over a relatively short period through an expansion of short rotation coppice and short rotation high yielding forestry crops.

Forest-based biomass is by far the dominant component of biomass supply and is likely to remain so. Recent work (Phillips 2012) points to a planting programme approaching 15,000 ha per annum in the period leading up to 2020 and beyond, as necessary for forests to provide a sustainable level of supply of forest-based biomass.

The future development of the emerging wood energy sector is dependent on a sustainable and increasing supply of raw material including small roundwood and wood residues from the processing sector. To date there has been little information provided within the Republic of Ireland (ROI) on the availability or otherwise of roundwood and wood residues for energy apart from the inclusion of a wood energy assortment in the private sector forecast (Phillips et al. 2009). This has led various potential investors to interpret standard forecast outputs and woodflows in an effort to estimate what level of future wood fibre is potentially available for energy.

Against the background of government support schemes for the use of wood energy, increasing investment in wood pellet and combined heat and power (CHP) plants and an expanding wood chip market for domestic and businesses, there is now an urgent need to provide an estimate of the potential wood fibre availability for energy use. This will facilitate investment decisions on future facilities and inform policy makers.

SupplyChip Objectives

Against this background of increasingly demanding national targets for renewable energy, increasing demand for wood fibre to meet these targets, expanding wood exports from the processing sector and a relatively flat roundwood forecast from state owned forests, any increase in future supply is dependent on increased harvesting within the privately owned forests. In addition, future forecasts must if they are to meet the needs of industry provide detailed estimates of wood energy assortments and also provide robust catchment based potential supply volumes bearing in mind the issues of accessibility and site productivity.

The SupplyChip project is timely in that it not only provides forecast estimates of energy wood assortment but also addresses the deficiencies associated with previous private sector forecasts as for example access and the basis for estimation productive capacity (yield class). The main objectives are to:-

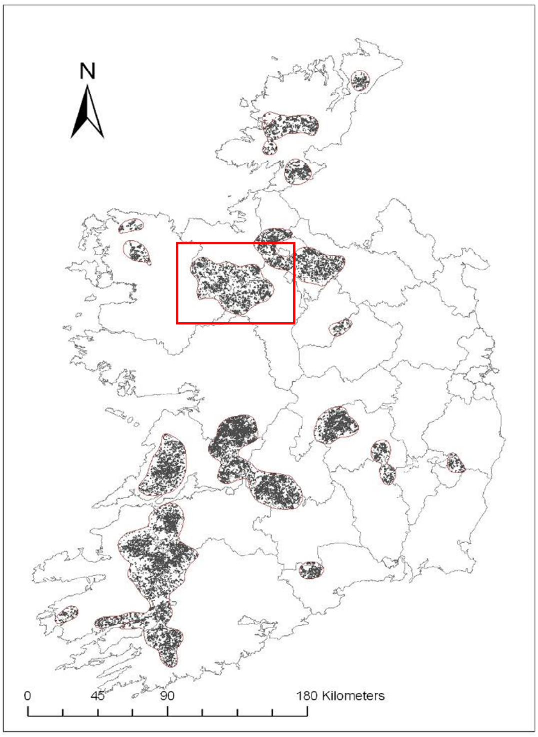


Figure 2: Ballaghaderreen Cluster

- Quantify the likely breakdown by volume of wood energy assortments within an identified cluster area i.e. Ballaghaderreen, County Roscommon;
- Examine the roading infrastructure, both national county and within forest networks that will facilitate harvesting of forests for wood energy; and
- Provide a wood energy flow to potential users (co-fired power plants, CHP plants and industry) through the ranking of plantations based on roading infrastructure, wood energy potential and haulage distance to end users.

The Ballaghaderreen cluster study area encompassed 3,276 privately owned forest plantations occupying circa 11,500 ha.

The methodology developed during the project together with the findings will be capable of being repeated either in other identified clusters or within specified catchment supply areas.

The project builds on the work of the CLUSTER project which following the development of a comprehensive private forests dataset used spatial analysis techniques to identify 16 areas of high private forest concentration (clusters) throughout the country. The clusters accounted for 42% of the private grant aided area (PGA) while occupying only 14.5% of the national land area. The aim was to address the critical issue of economies of scale among private forest owners.

The CLUSTER project selected the Ballaghaderreen area to undertake a case study to test a methodology to quantify the forest resource and thereby provide the basis for the allocation of future management regimes. This entailed dividing the area into four age based strata and the oldest stratum was used to collect field data on the forest crop. This was based on a sample of 92 individual forest owners covering 932 ha or 20% of the strata. This enabled the forecasting of timber volumes within a distinct geographic area.

The SupplyChip project utilises the Ballaghaderreen cluster and expands on the data already collected but in particular on the question of accessibility and the basis for determining the future management regime of the forest areas. It differs from the CLUSTER project in that it is not based on sample data from part of the cluster, rather it utilises the information from each of the forest areas within the cluster.

Methodology

This section of the report describes the data input sources used to develop the forecast of energy wood and what information had to be added in order to develop a new layer of forest inventory cover for the Ballaghaderreen cluster area. It also describes the approach adopted to allocate management regimes to privately owned forests and the field validation process. The forecasting rules and assumptions are defined.

Data Sources

To overcome some of the shortcomings arising from input datasets used in previous forecasts for private sector forests, the project decided to develop a new forest cover inventory layer for the Ballaghaderreen cluster area. This new layer would provide a more robust basis for forecasting volumes and the methodology to develop it could be replicated for other forest clusters or catchment areas.

The three basic input datasets were:-

- **a)** Forest07 (Premiums + FIPS98);
- **b)** WP08; and
- **c)** Cluster Dataset.

A forest classification project undertaken in the early 1990s succeeded in categorising Ireland's forests into broad species and development classes (Gallagher *et al* 1996). The output from this work was the FIPS95 (Forest Information and Planning System) dataset which included 504,000 ha of public and private forests. In 1998, private afforestation records were appended to FIPS95, but only for those plantations in receipt of grant / premium aid at the end of 1998. This new dataset was called FIPS98.

In 2006 the Forest Service began working towards an update of the FIPS forest cover layer for the private estate. This new forest cover layer is referred to as Forest07. The Premiums data were extracted from the IFORIS database and refer only to private plantations. This includes plantations that were in receipt of premium in 2005, when IFORIS went live. All plantations with a spatial component in IFORIS were extracted and given attribute information. The attribute information included: planting year and species. As the Premiums dataset contains only those plantations that were in receipt of premium when IFORIS went live in 2005, the earliest planting year available is 1989.

The Premiums dataset and FIPS98 forest estate data were combined to produce Forest07. There are four distinct ownership categories in the Forest07 dataset which can be summarised as follows:

1. **Private Non-Grant Aided (PNGA)**. The forest area in this ownership category generally includes forest areas planted prior to 1980. This encompasses old estate plantings, as well as natural succession and other scrub type broadleaf woodlands. This data originated from FIPS95 and has broad species information.
2. **Private Grant Aided (PGA)**. This portion of the dataset was captured from private grant applications which were delineated on OSi hard copy maps. These forest areas were in receipt of grant aid. No species or other attribute information is available for this portion of the estate. This data originated from FIPS98.
3. **Premiums**. The private forest area in this portion of the dataset has comprehensive species details attached.
4. **Public**. Forest land owned by Coillte and the National Parks and Wildlife Service are included in this category. This data originated from FIPS95 and has broad species information.

The Forest07 dataset provides detailed information on 679,485 ha of Ireland's forest estate of which circa 45% is in private ownership.

In 2008 the Forest Service compiled a spatial database of privately owned plantations afforested between 1980 and 1990. This focused primarily on plantations established under the Western Package (WP) scheme, but also included the State Scheme (NPG), Farm Forestry Scheme (AH) and Planting Grant Scheme (PG) as these schemes were operational during the 1980-1990 period. Due to the duration of the schemes, forest areas with planting years ranging from the 1960s (PG) up to the mid 1990s (WP) were included. Hardcopy files formed the basis of the data capture process. The areas identified on the hardcopy maps were digitised using the OSi 2004 air-photos. The plantation area was then attributed with the species and planting year information detailed in the file. In excess of 27,000 ha were digitised and the dataset is known as WP08.

The CLUSTER project combined the FIPS98 and the Premiums dataset extracted from IFORIS to form one master database with full coverage of the private grant aided sector. Extensive spatial analysis and quality control procedures were used to eliminate duplicates and to realign external boundaries with features from the orthophotos. Stand area, townland location and elevation were derived from additional spatial datasets and a digital elevation model (DEM). Additional value-added data was derived from aerial orthophotography (1995 and 2000) and quickbird imagery and included the stage of crop development (ground preparation, pre-thicket, thicket and pole), age and an estimate of stocking.

Aerial Photography analysis

Development Stage

The Ordnance survey Ireland orthophotography (1m resolution) was used in conjunction with the OSi 1:50,000 maps and 6 inch maps. The initial phase of aerial photography analysis involved updating the existing spatial database. Each plantation in the study area was visually assessed and its attributes noted in the GIS. The database was updated to include information on whether the plantation was visible in the 2005 orthophotos, and the stand's development stage. A decision tree was developed in the CLUSTER project to aid classification and these classifications were updated for each forest stand. The classifications used were:-

1) **Ground Preparation**: Planting lines strongly visible with little sign of vegetative material;
2) **Pre-thicket**: Planting lines visible with evidence of vegetative material;
3) **Thicket**: Foliage starting to merge between lines; and
4) **Pole**: Evidence of canopy closure and a mature crop.

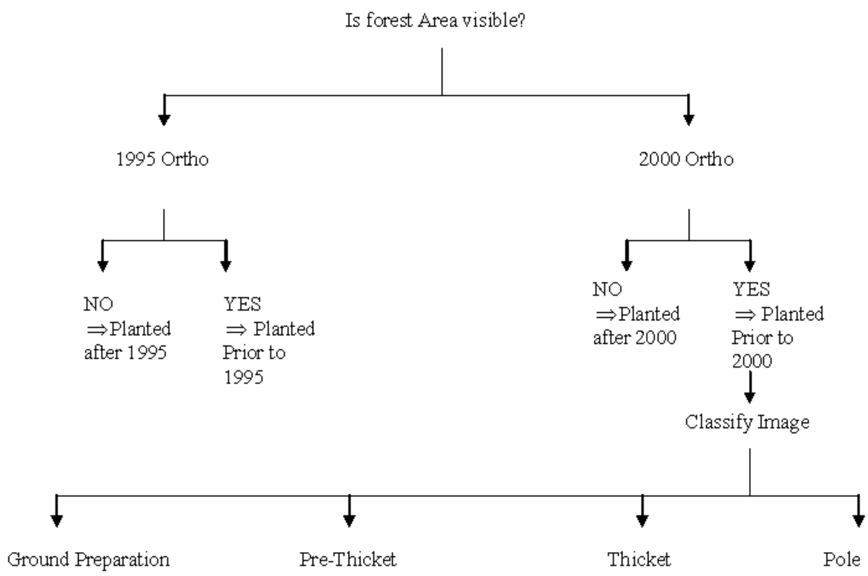


Figure 3: Forest Stand Classification (Farrelly and Clifford, 2009)

Sites with a Forest Service contract number but not visible on the 2005 photographs were checked on the OSI reference base map to ascertain whether the plantation was present or not. This occurred when plantations were grant aided but not planted by 2005.

Site classification information was derived using OSi 6 inch to 1 mile (1:10,560) maps. These maps are furnished with historical information pertaining to vegetation and field boundaries. The underlying Ordnance Survey map ornament and whether the land was enclosed or unenclosed were also assessed. Using these maps, each site was classified into four land-use types according to O'Carroll's (1975) site fertility classification, as follows: (A) fields and ornamental ground; (B) presence of furze (Ulex spp.); (C) rough pasture with or without outcropping rock; and (X) old woodland.

Figure 4 Recently Thinned Stand, Adjacent to County Road

Missing Stands

All plantations which were included in the input datasets were checked against the 2005 aerial photography. Where the stand was not visible on the orthophotography, it was excluded from the database. Where a stand was visible on the orthophotography but not included in the database, the database was updated to include the forest area.

Productive Area

None of the input datasets contained any information on the presence or otherwise of unproductive areas within plantations. The previous private sector forecasts used general national level assumptions on the extent of unproductive areas and what stocking factor to use when determining net forecast volumes. Rather than continue with this general approach, each stand was visually assessed using aerial photographs to determine the percentage productive area. Thus stands with failed or unplanted areas had their effective area reduced.

Access

One of the limitations of the two recent private sector forecasts is the lack of information on the accessibility of plantations. The All-Ireland forecast (Phillips, 2011) did attempt to identify and exclude private plantations with a potentially uneconomic forest roading requirement. To address this limitation, each of the 3,276 stands in the study area was assessed using aerial photos and road maps. Whether a stand was adjacent to a county road or the distance to the nearest county road were recorded as was the road class. Four accessibility classes were used:-

- **a)** Not adjacent;
- **b)** Adjacent;
- **c)** Within 50m of a third class road; and
- **d)** Within 50m of a fourth class road.

Based on the assessment, 88% of the study area was classified as being reasonably accessible to the public road network i.e. within 50m of a third or fourth class road, with the remaining 12% were classed as inaccessible and as a consequence unlikely to be thinned. The 88% classed as being reasonably accessible is higher than the national average for private plantations which the All Ireland forecast estimated as being 64% of plantations within 50m of a fourth class road. This is attributable in part to the concentration of plantations within the cluster study area.

The presence of internal forest roads was also recorded and whether the stand had been thinned.

An automated proximity analysis was performed using the GIS software to analyse the distance from each stand to the public road network. This while useful, had its limitations as it could not account for barriers such as rivers or other obstacles which could prevent a forest being accessed by the nearest public road.

Appending Spatial Data

A significant part of the SupplyChip project concentrated on improving the basic dataset by appending additional spatial data to each of the 3,276 forest stands. Some of these data were necessary to assign potential productivity (yield class) and to derive the thinning potential of individual stands, while others allowed for a more comprehensive information base for future analysis and interrogation.

The following list indicates the scope of the information that was appended:-

- **a)** Soil group based on the Irish Forest Soil Types (Fealy et al. 2006);
- **b)** Land Use Type (LUT);
- **c)** Elevation based on OSi digital elevation model (DEM);
- **d)** Mixture type;
- **e)** Stage of crop development;
- **f)** Fertility class;
- **g)** Soil parent material;
- **h)** Productive area;
- **i)** Windspeed;
- **j)** Thinning status; and
- **k)** Ground conditions.

Site Productivity - Yield Class

There is no reliable source of information on yield class for privately-owned forests. It is not available in the National Forest Inventory (NFI), FIPS98 or the Forestry07 datasets. The forest management plan required by the Forest Service for grant-aided crops does record a notional yield class but this information is available only in hard copy and its reliability has never been validated.

Yield class was calculated using the *Forecast Model* described by Farrelly *et al*., (2011) (soil, parent material, fertility class and windspeed). This model relates forest productivity to low resolution digitised data, such as soil maps and easily assessed variables describing site quality such as site and vegetation classifications. The model was designed to predict General Yield Class (GYC) of Sitka Spruce based on these variables. The model accounts for 49% of the total variation in yield class which is superior to that used in the 2009 private sector forecast.

Where Sitka spruce was the first species within the stand, then the average weighted yield class was 23.5 with a range extending from yield class 12 to 30.

In order to estimate forest productivity for other species, a look-up table based on expert knowledge similar to that used in the 2009 private forecast was used. The look-up table was augmented to include the full range of yield classes possible within the *Forecast Model*.

Thinning Potential and Rotation Length

In order to evaluate the potential of each forest stand as a source of thinning output for wood energy, a decision tree was designed (Figure 5). This decision tree looked at plantation area, public road access and ground conditions. The suitability of each site for thinning was evaluated using specific criteria under these headings and a thinning and rotation regime / classification then applied to each stand. The classifications used were as follows:

- **Standard thin**. Crop is thinned to marginal thinning intensity on a 5 year cycle until standard rotation age.
- **Reduced thin**. Crop is thinned twice to marginal thinning intensity five years apart and a reduced rotation applied
- **No thin**. Crop is not thinned and is grown on a reduced rotation.

Plantation area was assumed to be the most significant factor in whether a plantation will be thinned. The field work, described elsewhere was used to validate this assumption. The assumption was that plantations of greater than 10 hectares were extremely likely to be thinned, plantations of 5- 10 hectares are quite likely to be thinned, and plantations of under 5 hectares are unlikely to be thinned. Notwithstanding this assumption, small stands of broadleaves can be attractive for thinning for the local firewood market. Of the 3,276 stands within the cluster, some 1,277 were less than 5 ha and accounted for 18% of the forest area. 90% of the area was deemed suitable for thinning, with 64% (7,200 ha) allocated a standard thinning and 26% (2980 ha) allocated a reduced thinning.

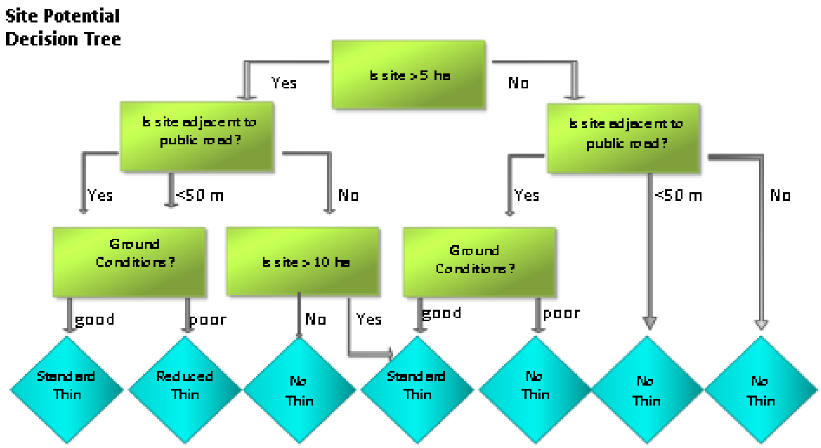


Figure 5: Forest Management Regime Decision Tree

Ground conditions were the second most important factor in making the thinning decision. In order to calculate ground conditions, a centroid was generated for each plantation polygon and this was overlaid on the General Soils Map (Gardiner and Radford, 1980). From this, soil type was found for each plantation and ground conditions classified as being either good or poor.

The timing of first thinning was based on the Forestry Commission yield tables (Forestry Commission, 1981).

Standard rotation lengths were determined for conifer species based on the findings from a previous economic analysis (Phillips, 2008). However the price data were updated and the basic economic model rerun to validate the rotation lengths used. Broadleaved species were assigned a rotation of maximum mean annual increment (MMAI).

The reduced rotation length for conifers was based on the age required to reach a top height of 21m. Where this age was either within four years of the standard rotation or greater than the standard rotation age, the reduced rotation was made equal to the standard rotation minus five years. For example, a Norway spruce yield class 10 crop reaches 21m top height at age 63 years. However, the standard rotation age is 52 and thus the reduced rotation is equal to 52 minus 5 or 47 years.

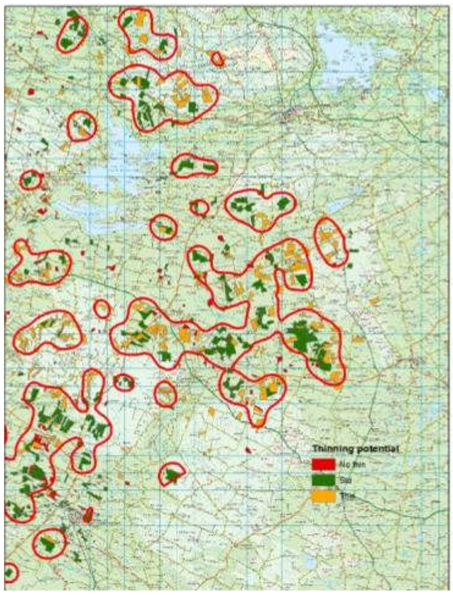


Figure 6: Thinning Potential Ballaghaderreen Cluster

Field Validation

Two field validation surveys were undertaken. The first field visit focussed on ground truthing and correlating the visual assessment from the aerial photography with actual conditions on the ground. A total of 12 sites were chosen from the 2005 orthophotos which were assessed as being productive and that would be suitable for thinning by 2011. The quality of access to each site varied significantly and it was decided to investigate what access was available on the ground as well as assess the thinning status of each stand. The field survey confirmed the reliability of visual assessments using aerial photography for productive area, access and determining thinning potential.

In the second field survey a total of 20 sites were selected at random. Half of the sites were less than 5 ha and half within the range 5 - 10 ha in size. In addition to validating assessment of productive area, access the field survey also focussed on the relationship between plantation size and thinning status. The survey confirmed the assumption that smaller plantations were more likely to remain unthinned, especially when access to a public road is an issue.

Forecasting Rules and Assumptions

Yield Models: The Forestry Commission (FC) yield models for forest management (Forestry Commission, 1981) have been widely used to forecast future volume production at a stand, forest and national level. The models are based on the yield class system of growth classification and on research and plot data from the United Kingdom (UK).

There are a wide variety of models encompassing different tree species, growth rates (yield classes), thinning treatments and initial tree spacing. The models are however static and as such assume certainty about the starting position of a stand and how that individual forest stand will be managed over time. The FC models relating to 2m x 2m spacing or their nearest equivalent were used for conifer species. The range of models for broadleaved species is limited generally to one spacing and thinning type and this was used.

The FC models, although they have a number of shortcomings, have provided a uniform basis to forecast volumes.

Assortment Tables: Volume assortment tables provide the proportion of volume in one or more size categories based on the average stem diameter which by convention in Ireland is measured overbark and on a minimum length size measured in metres, usually 3 metres. The three standard size categories, based on top diameter, commonly used are (1) 7cm to 13cm, (2) 14cm - 19cm and (3) 20cm and greater and these were adopted. In addition the volume from 7cm to the tip of the tree was calculated. It is important to clarify that these are size categories and do not equate to product classes e.g. sawlog, due to underlying assumptions regarding log lengths and timber quality. Forestry Commission assortment tables were used to allocate volumes to the four size assortment categories (Matthews and Mackie, 2006).

Stocking: Traditionally a 15% reduction in forecast volumes has been used in Ireland to allow for roads, rides and other unproductive areas within the forest. The same approach is also used in the UK (Forestry Commission, 1981). As outlined previously, the productive area of each stand was assessed using aerial photography and validated through field visits. This productive area needed to be further adjusted for future internal roads, stacking areas, turning bays and road exits. Stands assessed to have a productive area equal to or greater than 85% had a reduction of 15% applied, while stands with a productive area of less than 85% received no adjustment.

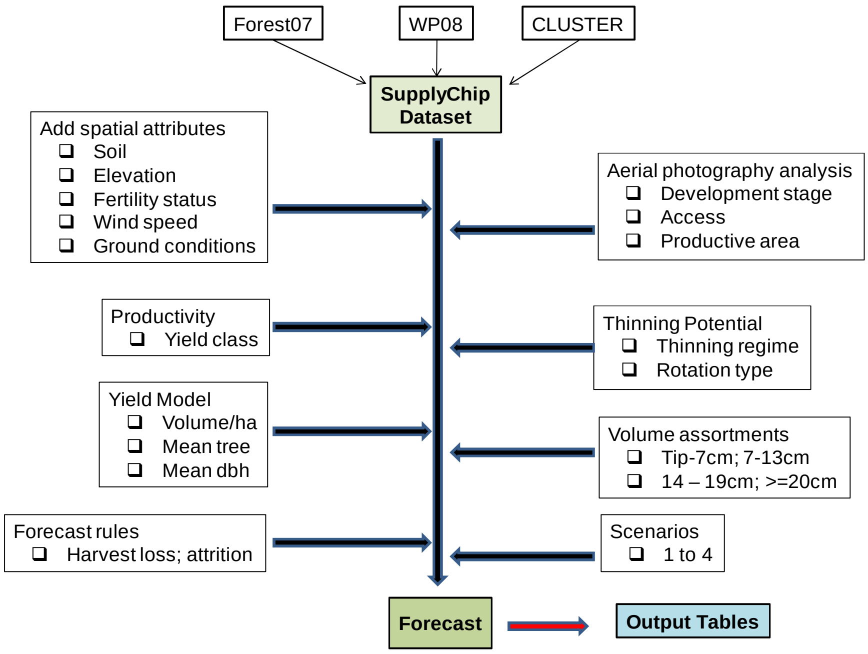


Figure 7: SupplyChip Forecasting Process

Attrition: Attrition is the loss in productive capacity due to the incidence over time of windthrow and disease. A default attrition factor of 5% was used. This 5% was converted to an annual attrition volume between the age of first thinning and the age of MMAI and was deducted from forecast volumes.

Harvest loss: To allow the forecast to estimate energy wood volumes post harvesting at roadside, it was necessary to determine the extent of harvest loss. The private sector forecast had used a series of default values based on an analysis of sales lots from Coillte. These values were adjusted downward to reflect that thinnings volumes within the cluster were being directed at energy markets.

Species per Stand: A maximum of four species per stand was used. Where there were more than four species, the area was allocated proportionally between the first four species.

Scenarios

Harvested roundwood is a flexible raw material in that it can be directed to a number of potential markets. Thus small sized roundwood (7-13 cm) could be converted to stakewood, pulpwood, domestic firewood or wood energy. The proportion of the size assortment that ends up converted to a specific product is a function of a number factors including price, proximity to market, species, timber quality and product specification. While it is possible to estimate the volume of potential end products in a given stand, the market will dictate the final outcome.

Four possible wood energy supply scenarios were identified.

a) Scenario **S1**: 40% of the 7-13cm assortment goes to wood energy;
b) Scenario **S2**: 40% of the 7-13cm and all tree tops (tip -6cm) go to wood energy;
c) Scenario **S3**: 100% of the 7-13cm and all tree tops go to wood energy; and
d) Scenario **S4**: 100% of all size assortments go to wood energy.

The range of scenarios recognises that energy wood has to compete with existing markets for raw material supply. Scenario S4 is considered somewhat unlikely and is predicated on a situation where energy wood could compete on price with roundwood destined for the sawmill sector. The SEAI supply curves for 2020 and 2030 show an increasing volume of forest thinnings becoming available as the price increases to around €500/toe or circa €74 per m^3 delivered to the end using facility. By way of reference oil at $100 per barrel equates to €570/toe.

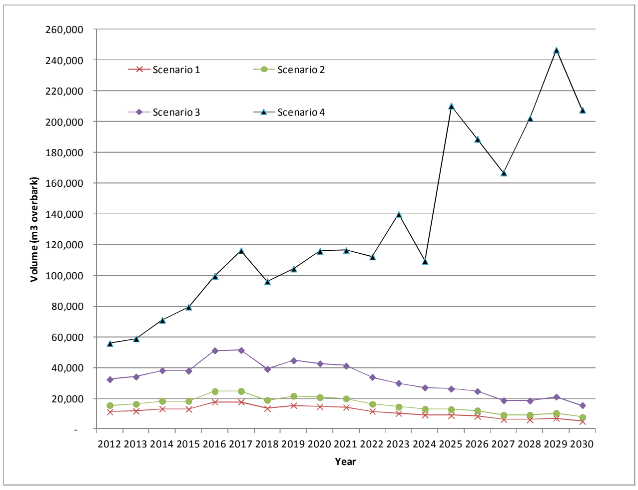
None of the scenarios envisages the use of branch material (lop and top) for wood energy. Although a proportion of the larger sized assortments will be processed by the sawmills and in turn generate potential wood energy co-products e.g. wood chip, sawdust, this has not been factored into any of the four scenarios as it was assumed that this energy source would be used primarily by the processing facility and not be wholly available to a third party.

Scenario Analysis

The forecast potential wood energy flows from 2012 to 2030 under the four scenarios are shown in Figure 8 and Appendix 1. At the outset, it is important to note that future timber production is directly correlated to the age, forest productivity and future management regimes of the plantations within the cluster area. No allowance has been made for new planting, which would supplement the existing forecast in the early to late 2020s. Under this assumption with no new planting or no establishment of SRCs, it is inevitable that the small sized volume assortments which will go to energy wood will decline over the life of the individual plantations as they mature and their average tree size increases.

Under scenario S1, wood energy potential is forecast to increase from 11,000 m^3 in the first year of the forecast to reach a maximum of 18,000 m^3 per annum in 2017, then decline gradually to 14,200 m^3 in 2021 and thereafter to decline more rapidly to 5,100 m^3 in 2030.

Under scenario S2, the inclusion of additional material from the tree top assortment increases the estimated forecast wood energy supply to 25,000 m^3 by 2017. Thereafter the forecast supply follows a similar pattern to scenario S1, decreasing gradually to 15,000 m^3 in 2023 followed by a more rapid decrease to 8,000 m^3 by 2030.



Under scenario S3 which assumes that 100% of the small roundwood and tree tip assortments will go to energy wood, there is a significant increase in the forecast energy wood volumes over the period of the forecast. The forecast supply increases from a starting value of 32,000 m^3 in 2012 to reach a peak of 45,000m^3 in 2019. Thereafter forecast supply decreases gradually to 30,000 m^3 by 2023 and then more rapidly to 16,500m^3 by 2030.

Figure 8: Wood Energy Supply Scenarios

Under scenario S4, which assumes that all harvested wood volumes goes to energy wood, the forecast supply increases steadily with some fluctuations from an initial volume of 56,000 m^3 in 2012 to reach a peak of 247,000 m^3 in 2029 followed by a decline to 208,000 m^3 in the final year of the forecast. There are a number of peaks and troughs in the forecast supply, reflecting significant clearfell areas and the age class distribution of plantations within the cluster area. No smoothing of forecast volumes was undertaken to even out these variations over the forecast period. Any smoothing would have only a minor impact on the overall volume production within the forecast period.

Suitability of Supply to End users

Under scenario S1 where only 40% of the forecast small roundwood goes to energy, local wood markets, have the most potential and given the lower cost of haulage and the lower quantities, lower end boiler facilities in any of the major towns within the cluster area could rely on potential sustainable supply from these local forests (Figure 9).

Larger facilities such as the proposed boilers in Ballaghaderreen (12 MW steam boiler to dry milk in a major dairy plant year-round) would require significantly more material estimated as being of the order of 35,000 - 40,000 m^3 of round wood equivalent at 55% moisture content. Under scenario S1, even if all the wood energy material was diverted to such a facility only about 30% of the wood energy requirement of such a boiler could be met.

However with the increased volumes under scenario S2 which includes the tree tip assortment, approximately 50% of the demand for a 12 MW boiler could be met up to 2022 with a decreasing forecast supply after this point. The shortfall in supply from 2022 onward could possibly be met through additional supplies of wood co-products from the wood processing facilities e.g. wood chips.

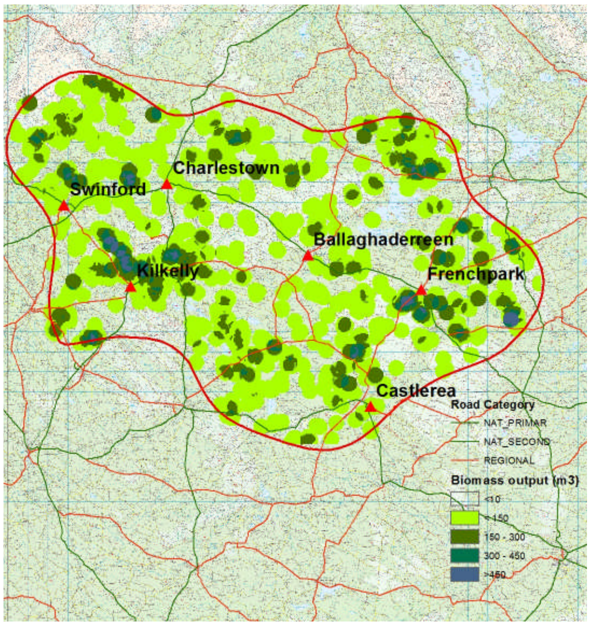


Figure 9: Supply to Potential Local Using Facilities

Under scenario S3, where 100% of small roundwood and the tree tip assortment goes to wood energy, there is more than sufficient volume to meet the demand associated with a 12 MW steam boiler. However, to leverage all of the small roundwood would require a price for energy wood that makes it attractive relative to more traditional markets such as stake wood or local markets for firewood and or chips. As markets for this material are limited, and haulage distance is a critical factor controlling profitability, local markets may be in a position to leverage part of the supply.

In terms of wood flows/potential supply to larger co-firing facilities (e.g., Lanesborough), then the only scenario that offers any sort of scale of supply is S4 where all of the harvested material goes to energy wood. This is perhaps somewhat unrealistic; especially when one considers that haulage will be to outside of the cluster area thereby reducing the price potential end users could pay. Notwithstanding this reservation, there is scope within this scenario to supply a significant volume to a suitably located large end user

The impact of augmenting potential supply through downgrade of the larger size assortments and/or part of the wood residue generated by the primary wood processing is examined under sensitivity analysis.

Table 3: Scenario Analysis - Potential End Users and Demand Levels

User	Potential Users	Demand	Likely Scenario	Comments
Local Level	Town based facilities (nursing homes, etc)	<20,000 m^3	S1	Sufficient available wood energy under scenario for 10 - 20 local facilities
Medium scale	Ballaghaderreen (12 MW steam boiler)	35,000-40,000 m^3	S3	Only scenario 3 offers a realistic supply, likely will have to rely on additional sawmill residues with scenario 2
Industrial scale	Lanesborough (co-firing)	100,000 m^3	S4 S1-3 with increase of catchment area to 40,000 ha	Only scenario 4 offers a realistic supply, would have to rely on additional volume assortments or increase catchment area.

Sensitivity Analysis

There are three main sources of raw material for wood energy – small roundwood from thinnings, wood residues from the processing sector and post consumer recycled wood (PCRW). Additional raw material is potentially available through the harvesting of lop and top (including branches and some harvest loss material) on suitable sites. In compiling an estimate of wood fibre potentially available for wood energy, the All Ireland forecast (Phillips, 2011) assumed that:-

a) An increasing volume of downgrade material from the larger size assortments in the private sector will be available for wood energy; and
b) An increasing volume of wood residues from the processing sector will be available for wood energy.

As the harvesting of lop and top is at a relatively early stage of development in Ireland and to date only economic on clearfell sites which meet a number of criteria, it is not considered within this sensitivity analysis. Assumptions or any analysis around the supply of PCRW is outside the scope of this project. This leaves only downgrade and wood residues.

Downgrade refers to the volume in a size assortment that for reasons of quality (straightness, branching or species) or length is only suitable for a lower end use product. Thus at the time of first or second thinning, there may be 20 m^3 of volume in the 14-19cm size assortment but only a proportion of this will end up as small sawlog (pallet wood). The proportion that is not suitable for conversion to small sawlog is termed downgrade. Historically for conifers between 65-70% of the 14 cm plus size assortments converts to sawable volume (Phillips, 2011).

Wood residues, also termed co-products, are by-products of primary processing (sawing) and comprise, bark, chips and sawdust. The largest user of these is the processing sector itself for heat which is used in drying the sawnwood. Not all of the residues are used on site for heat with some being used as raw material in the wood panels sector or as raw material for other energy users.

To estimate the impact on forecast supply, three possibilities were examined. The first was where 30% of the volume in the 14-19 cm assortment was downgraded and made available for energy wood. The second was where half of the estimated wood residues from the processing of the larger assortments, having made allowance for the downgrade, were made available for wood energy. The third possibility was a combination of the first and second. Forecast volumes are provided in Appendix 2.

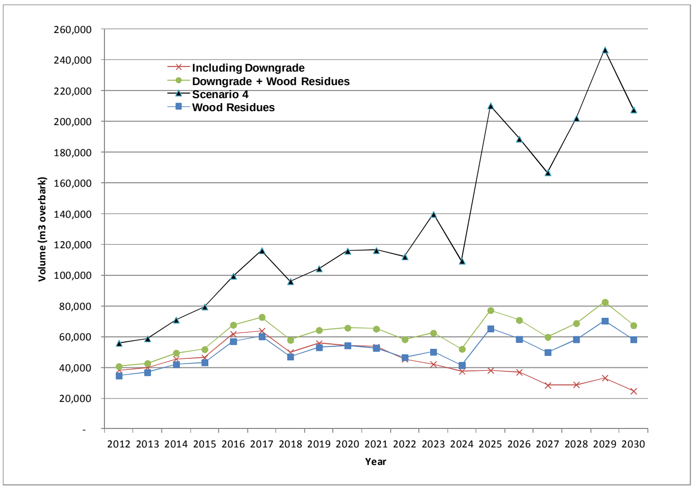


Figure 10: Supply Scenarios - Sensitivity Analysis

Including downgrade has the effect of increasing the level of supply which peaks at 64,000 m^3 in 2017 and then decreases to 30,000 m^3 towards the end of the forecast period. This average level of supply is sufficient to more than meet 100% of the requirements for a 12MW facility with the proviso requiring the purchase of some additional material in the last five year period. The rate of decrease in supply exhibited under scenarios 1-3 after 2020 has been lessened and a more sustainable supply is possible.

When 50% of the wood residues are made available, then not only is the level of supply increased but also and perhaps more importantly the shape of the supply curve. While there are some peaks and troughs, mirroring the total supply curve, the trend is upward over the period of the forecast increasing from 35,000 m^3 to 60,000 m^3. This level of supply is sufficient to meet not only a major end user of the order of 12MW but also to meet a significant proportion of anticipated local market needs.

When the combined impact of downgrade and wood residues are considered, the supply curve exhibits a similar shape to that for the inclusion of wood residues but there is a higher level of supply increasing from 41,000 m^3 to 70,000 m^3 within the forecast period. This level of supply, would be capable of meeting local market needs and one major user of 12MW.

Discussion

General

Good decisions require good information. Decisions on the future management of individual plantations require reliable inventory information e.g. species, stocking / productive area, yield class as well as information on local markets so that owners can make an informed decision on whether to thin and at what intensity and frequency. Decisions on investment in CHP or replacement of fossil fuels with locally sourced energy wood, requires reliable information on the future wood supply within a possible supply catchment(s). Obviously, the nearer the source of information is to the private forest resource, the more robust and reliable will be any forecast of wood flows be it for energy wood or the more traditional product assortments. Equally any potential investor in wood energy using facilities, be it a boiler for an industrial premises, or public building or a major investment like a CHP plant, will be more inclined to invest if there are supply forecasts based on local forest information as opposed to a more generic type forecast using a more broad brush approach to the underlying assumptions.

The SupplyChip forecast uses local stand information and improved spatial data to generate a local forecast for wood energy. This is a significant step forward as up until now, catchment or regional forecasts for the private sector relied on inferred data to a greater or lesser extent. Thus while the private sector forecast (Phillips et al, 2009) has the facility to generate a forecast for a 30k or 50k catchment around Ballaghadeereen, it uses high level assumptions which while they hold up nationally, need to be treated with caution at the catchment level.

The approach adopted by SupplyChip in focussing on a previously identified forest cluster, demonstrates the potential advantages of this approach in that it is possible to generate a sustainable supply chain for local market needs and or a significant locally based wood energy using facility. It is clear to potential end users where the supply is coming from and enables them to have a more informed view as to any haulage or other costs which may be incurred along the supply chain.

The benefits of using local information to generate local supply forecasts whether this be for a local producer group or for a potential end user or group of end users has implications for the COFORD working group on forest management planning. It will be important that any revised format for the management plan has the capacity to include the type of information that can input to the generation of robust local forecasts.

Strengths of SupplyChip Wood Energy Forecast

The rigorous and methodical analysis of the most recent aerial photography enabled the development of a more robust and accurate dataset. Missing stands were captured, non-existent stands were deleted and boundaries re-digitised where necessary. The end result was a "clean" and reliable basis for future development.

The appending of a wide range of additional spatial data enabled the development of much more comprehensive dataset capable of being used to support the future management of individual and groupings of private plantations. The appended data also enabled the objective allocation of yield class based on soil type, fertility class and average wind speed (Farrelly et al, 2011) as opposed to inferred values for yield class based on Coillte's forest estate (Phillips et al, 2009). The private sector forecast recognised the limitations of how yield class was allocated and due to the model used probably underestimated average Sitka spruce yield classes and probably more so in the higher yield class range. Thus any "increase" in average yield class could be interpreted as the added value of the project in the sense of more reliable yield class and increased volume resulting from this.

Limitations of SupplyChip Wood Energy Forecast

The three significant limitations of the SupplyChip approach and wood energy forecast are:-

a) The use of Forestry Commission yield models;

b) The limited range of management regimes; and
c) Lack of information on owners intentions.

The Forestry Commission models are based on UK data. The habit of tree growth in Ireland differs from that in the UK. Thus the FC models have tended to underestimate volume production under Irish conditions. Within the yield class classification system, this can be catered for by adjusting the yield class by measuring the production class. A yield class 16 crop with a production class "a" is equivalent in volume production to yield class 18, while the same crop with a "c" production class is equivalent to a yield class 14 crop. This adjustment is not generally applied, as it requires additional stand data and record keeping.

Despite the large number of models, there are some significant gaps as for example models with suitable initial spacing for hardwood species such as ash and the range of yield classes for Sitka spruce which does not go beyond yield class 24. For the higher yield classes, SupplyChip used the new models for Sitka spruce (Matthews, et al, 2009)) which have not yet been released publicly and which have not been tested or validated for use under Irish conditions.

The Forestry Commission models are static models and predict stand parameters (such as volume, stocking or basal area) over time based on assumed management interventions (thinnings). In this regard they are limiting as any deviation from the norm is not catered for within the model. Owners are more likely to follow the market rather than a rigid management regime as prescribed in the model.

The use of GROWFOR would overcome the two major limitations outlined above. GROWFOR refers to the software package that provides a user interface for the Irish suite of dynamic stand level growth models. In addition to facilitating interactive modelling of different management regimes, GROWFOR has some additional functionality such as the option to define different timber size assortments (Purser and Lynch, 2012). The models are derived from Irish data. Use of GROWFOR requires stand data (top height, age, number of stems, basal area and / or mean diameter breast height) which may not always be available as for example for relatively young stands. Currently GROWFOR is only designed to accept one stand at a time and as such not suited to forecasting volumes for the number of stands within a cluster.

Conclusions

The rigorous and methodical analysis of the most recent aerial photography together with ground truthing and validation of underlying assumptions enabled the development of a robust and accurate dataset which was further enhanced through the appending of a wide range of spatial data.

The estimation of site productivity (yield class) using the *Forecast Model* described by Farrelly *et al*., (2011) (soil, parent material, fertility class and wind speed) provided a more reliable basis than previous approaches based on either assumed averages or analysis of a sample inventory of state owned forests.

The methodology, building on the results of the completed Cluster project, demonstrates that it is possible to develop cluster area forecasts for privately owned forests based on individual stand data that are reliable and suitable as a basis to determine future wood energy flows and as a basis for investment decisions.

The methodology developed is capable of being replicated in each of the other 15 identified clusters and as such has all Ireland application.

Finally the project demonstrates that identified cluster areas of private plantations are capable of supplying sustainable levels of wood energy flows to a variety of end users while a major heat user can also potentially be provided with sustainable supply depending on the assumptions around downgrade and wood residues.

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Appendix 1: Forecast Wood Energy Supply

Wood Energy Net Realisable Volume (m3 overbark)

Production Year	Tip - 7cm	7-13 cm	14-19 cm	20cm +	Total> 7cm	Total> 7cm	Scenario SI	Scenario S2	Scenario S3	Scenario S4
2012	4,305	28,040	20,071	3,470	51,581	55,886	11,216	15,521	32,345	55,886
2013	4,601	29,408	19,947	4,905	54,260	58,862	11,763	16,365	34,010	58,862
2014	5,084	33,036	24,690	8,179	65,905	70,990	13,214	18,299	38,120	70,990
2015	5,232	32,619	28,493	13,154	74,267	79,498	13,048	18,279	37,851	79,498
2016	6,918	44,222	35,648	12,736	92,606	99,524	17,689	24,607	51,140	99,524
2017	7,045	44,285	41,852	22,982	109,119	116,164	17,714	24,759	51,330	116,164
2018	5,394	33,720	36,231	20,736	90,688	96,082	13,488	18,882	39,114	96,082
2019	6,145	38,500	37,296	22,457	98,252	104,397	15,400	21,545	44,645	104,397
2020	5,961	36,761	38,118	34,990	109,870	115,830	14,705	20,665	42,722	115,830
2021	5,656	35,506	41,199	33,939	110,644	116,300	14,202	19,858	41,162	116,300
2022	4,722	29,084	39,218	39,154	107,455	112,178	11,634	16,356	33,806	112,178
2023	4,358	25,498	40,950	68,949	135,397	139,755	10,199	14,557	29,856	139,755
2024	3,831	23,165	35,179	47,220	105,565	109,396	9,266	13,097	26,996	109,396
2025	3,995	22,209	39,715	144,395	206,319	210,314	8,884	12,879	26,204	210,314
2026	3,712	20,947	41,128	122,923	184,998	188,711	8,379	12,091	24,660	188,711
2027	2,921	15,723	32,733	115,454	163,910	166,831	6,289	9,211	18,645	166,831
2028	3,070	15,396	34,806	148,938	199,140	202,210	6,159	9,228	18,466	202,210
2029	3,360	17,723	40,650	184,935	243,308	246,668	7,089	10,449	21,082	246,668
2030	2,651	12,867	30,436	161,691	204,994	207,645	5,147	7,797	15,517	207,645
Totals	**84,657**	**510,671**	**638,289**	**1,207,738**	**2,356,699**	**2,441,355**	**204,268**	**288,925**	**595,328**	**2,441,355**
Average	**4,682**	**28,353**	**34,651**	**63,748**	**126,752**	**131,434**	**11,341**	**16,023**	**33,035**	**131,434**

Scenario S1	40% of the 7-13 cm assortment goes to wood energy
Scenario S2	40% of the 7-13 cm assortment and 100% of the ip - 7cm assortment go to wood energy
Scenario S3	100% of the 7-13 cm assortment and 100% of the ip - 7cm assortment go to wood energy
Scenario S4	100% of all size assortments go to wood energy

Appendix 2: Forecast Wood Energy Supply - Sensitivity Analysis

Wood Energy Net Realisable Volume (m3 overbark)

							Scenario 1 Plus			
Production Year	Tip - 7cm	7-13 cm	14-19 cm	20cm +	Total> 7cm	Total> 7cm	Downgrade	Wood Residues	Downgrade + Residues	Scenario S4
2012	4,305	28,040	20,071	3,470	51,581	55,886	38,366	34,718	40,739	55,886
2013	4,601	29,408	19,947	4,905	54,260	58,862	39,994	36,732	42,716	58,862
2014	5,084	33,036	24,690	8,179	65,905	70,990	45,527	42,017	49,424	70,990
2015	5,232	32,619	28,493	13,154	74,267	79,498	46,399	43,277	51,825	79,498
2016	6,918	44,222	35,648	12,736	92,606	99,524	61,835	56,998	67,692	99,524
2017	7,045	44,285	41,852	22,982	109,119	116,164	63,886	60,214	72,770	116,164
2018	5,394	33,720	36,231	20,736	90,688	96,082	49,984	47,016	57,885	96,082
2019	6,145	38,500	37,296	22,457	98,252	104,397	55,833	53,056	64,245	104,397
2020	5,961	36,761	38,118	34,990	109,870	115,830	54,158	54,329	65,764	115,830
2021	5,656	35,506	41,199	33,939	110,644	116,300	53,522	52,737	65,097	116,300
2022	4,722	29,084	39,218	39,154	107,455	112,178	45,572	46,536	58,301	112,178
2023	4,358	25,498	40,950	68,949	135,397	139,755	42,141	50,165	62,450	139,755
2024	3,831	23,165	35,179	47,220	105,565	109,396	37,550	41,440	51,994	109,396
2025	3,995	22,209	39,715	144,395	206,319	210,314	38,118	65,281	77,196	210,314
2026	3,712	20,947	41,128	122,923	184,998	188,711	36,998	58,475	70,813	188,711
2027	2,921	15,723	32,733	115,454	163,910	166,831	28,465	49,963	59,783	166,831
2028	3,070	15,396	34,806	148,938	199,140	202,210	28,908	58,311	68,753	202,210
2029	3,360	17,723	40,650	184,935	243,308	246,668	33,277	70,365	82,560	246,668
2030	2,651	12,867	30,436	161,691	204,994	207,645	24,648	58,223	67,354	207,645
Totals	84,657	510,671	638,289	1,207,738	2,356,699	2,441,355	786,815	945,134	1,136,621	2,441,355
Average	4,682	28,353	34,651	63,748	126,752	131,434	43,431	51,571	61,966	131,434

Downgrade	30% of the downgrade material goes to wood energy
Wood Residue	50% of the wood resudues goes to wood energy
Downgrade + Residues	30% of the downgrade material goes to wood energy plus 50% of the wood residues got to wood energy
Scenario S4	100% of the 7-13 cm assortment and 100% of the ip - 7cm assortment go to wood energy

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