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AN OWN CONSUMPTION WOOD ENERGY MICRO-CHAIN

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THE PROJECT

The project, financed by Italian Agriculture and Forestry Ministry, started in 2005 on the firm of the *Agricultural Engineering Research Unit CRA-ING, and finished in 2008*

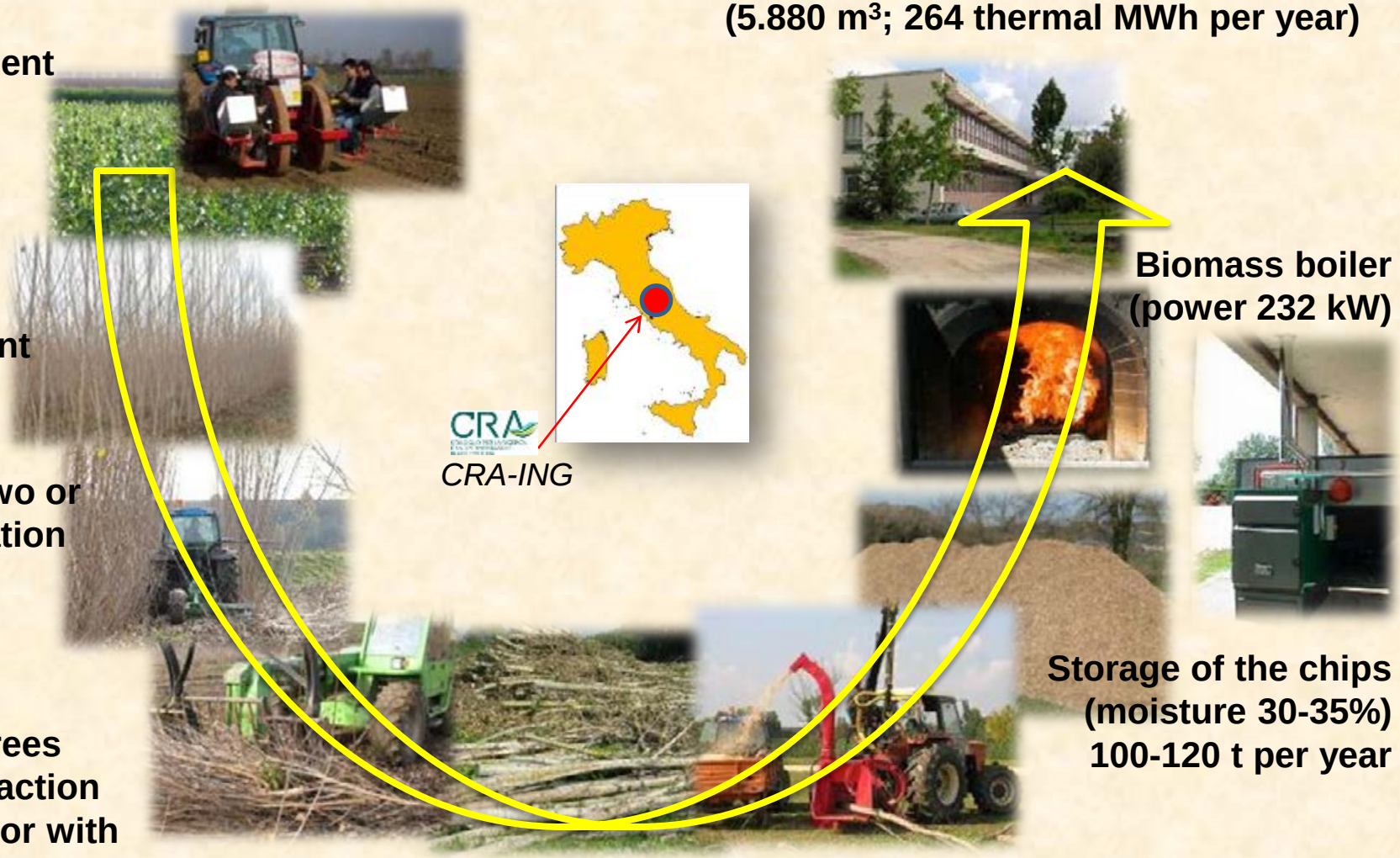
MAIN AIMS

- To verify the economic and energetic sustainability in relationship with the substitution of the actual thermal boiler that uses gas oil with another one fed with chipwood, for the institute's heating
- To find areas, in central-southern Italy, where the model could be repeatable
- To transfer this know-how to farmers interested in using biomass to produce thermal energy

SECONDARY AIMS

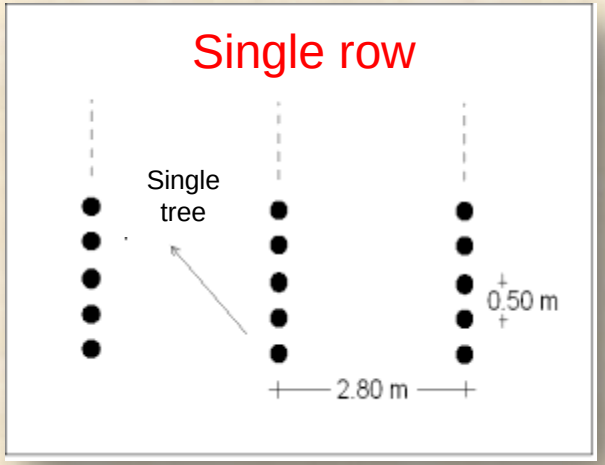
- To select the best poplar clone employed and the cultivation module
- To determine the best level of mechanization for harvesting
- To select actions to constrast eventual insect pests and fungal diseases

CRA-ING MICRO-CHAIN MODEL



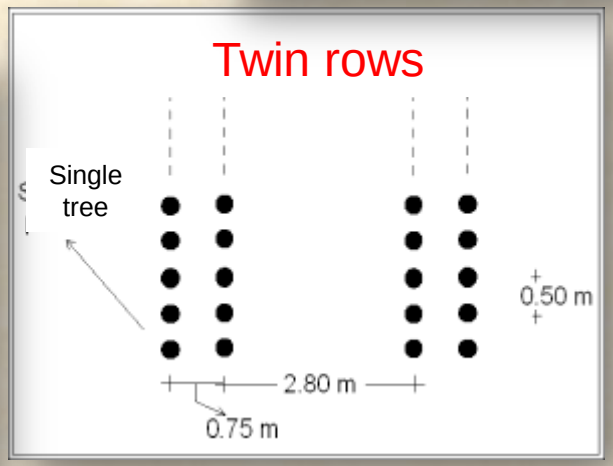
OPERATIONS CHRONOLOGY

- March, 2005 - The plantation was established (4 hectares of poplar SRC, single and twin rows). Poplar clones AF2, AF6, and Monviso were employed
- February, 2006 - The cut back, to favour the coppice's growth, was made
- March, 2006 - 0.7 hectares of SRC and 2.3 hectares of MRC were established. The same poplar clone were employed
- Winter, 2006 - The new thermal boiler was activated
- December, 2007 - The SRC was harvested



7,140 cuttings per hectare

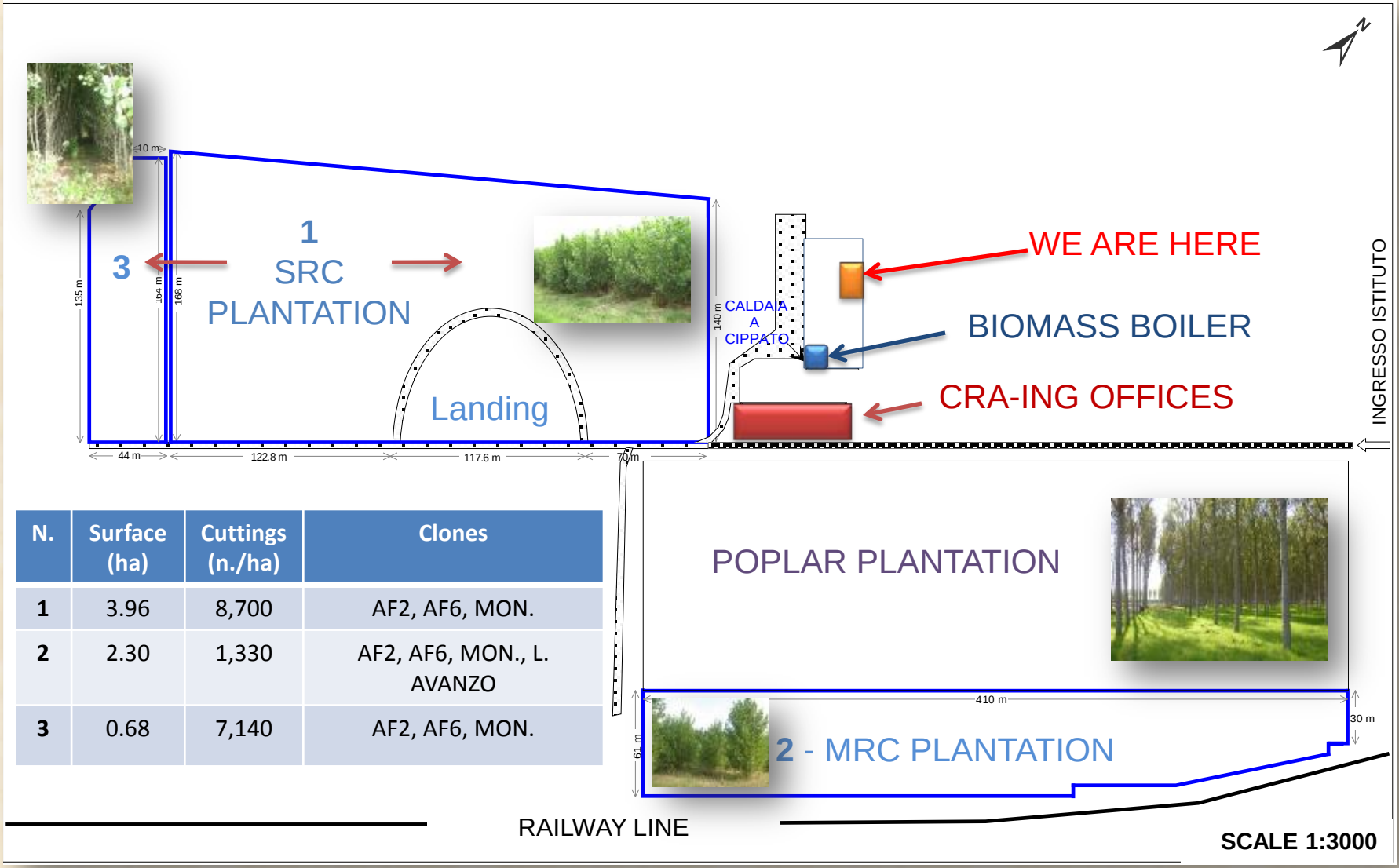
Transplanting machine



10,360 cuttings per hectare

PLAN OF THE PLANTATIONS AND BUILDINGS

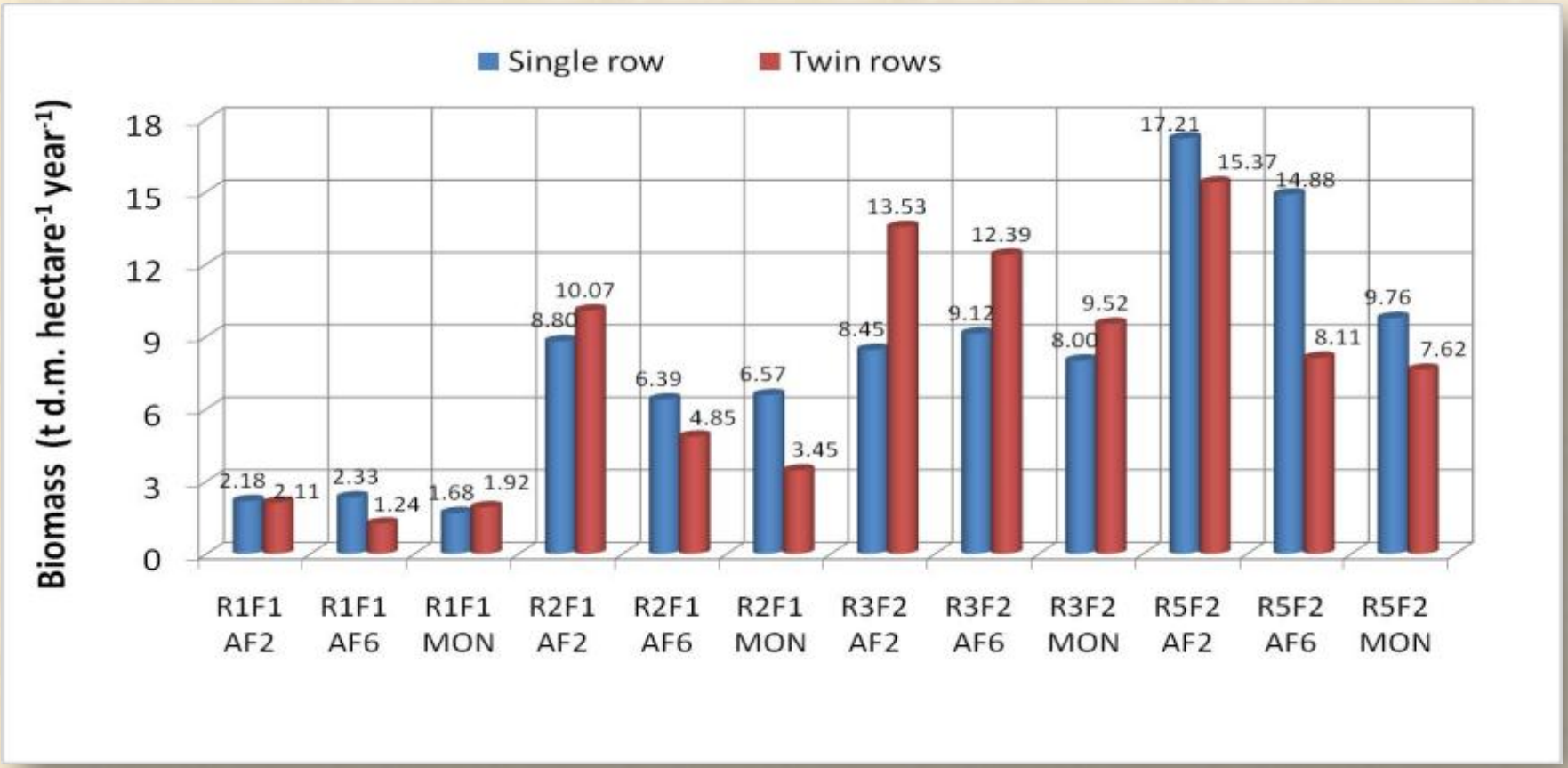
Scheme of the SRC-MRC plantations and of the structures



N.	Surface (ha)	Cuttings (n./ha)	Clones
1	3.96	8,700	AF2, AF6, MON.
2	2.30	1,330	AF2, AF6, MON., L. AVANZO
3	0.68	7,140	AF2, AF6, MON.

CHARACTERISTICS OF SRC PLANTATION

Average DBH of the clones



Average DBH of SRC plantation at different sprouts age.

(R1 F1: root 1 year stem 1 year; R2F1: root 2 years stem 1 year; R3F2: root 3 years, stem 2 years; R5F2: root 5 years stem 2 years).

R5F2 vs R3F2: Average DBH

Single row +28%

Twin rows -2%

CHARACTERISTICS OF SRC PLANTATION

Height and number of trees per hectare

Number of sprouts (per hectare)

Single row

	R3F2	R5F2
AF2:	27,704	23,313
AF6 :	31,095	20,312
MON:	25,616	14,831

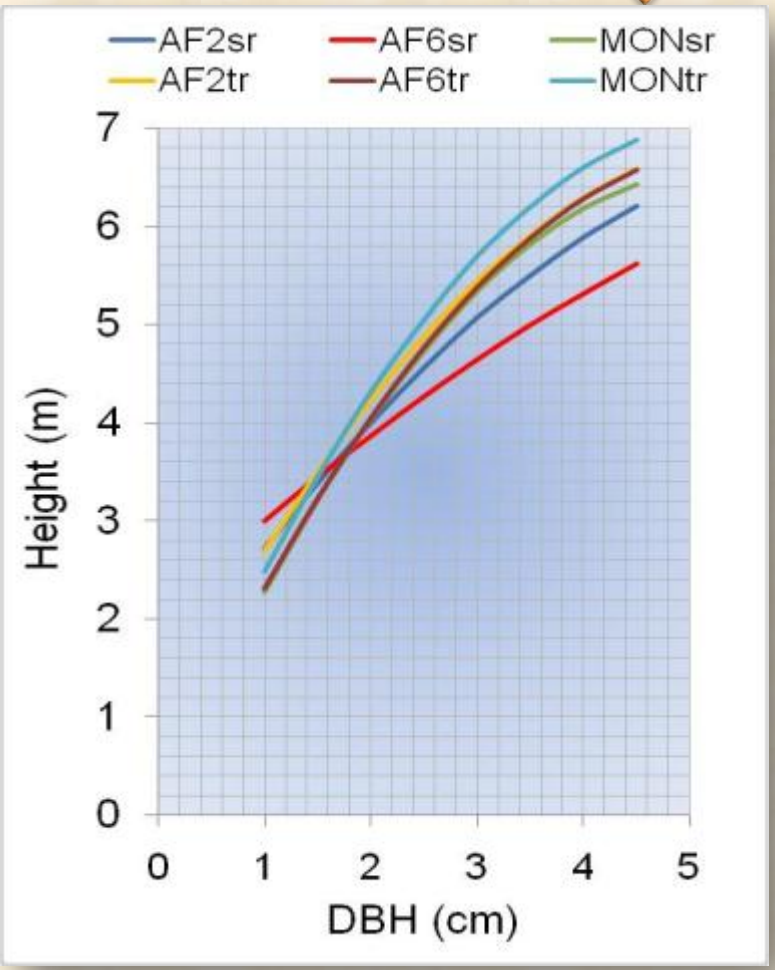
Twin rows

	R3F2	R5F2
AF2:	29,400	21,391
AF6:	25,299	15,449
MON:	17,944	15,009

Sprouts per stump (N.)

	R3F2	R5F2
Single row:	4.30	2.97
Twin rows:	2.60	1.80

Height as a function of DBH for three clones employed and for single (sr) and twin rows (tr) at the third vegetative season (R3F2)



DBH = Diameter at Breast Height

CHARACTERISTIC OF SRC PLANTATION

Moisture and weight (R3F2)

Plant typology	Clone	Average moisture (on fresh weight) (%)	Bark (on fresh weight) (%)	Bulk density (kg/m^3)
Single row	AF2	51.56	28.85	670
	AF6	52.68	29.03	785
	MONVISO	53.39	27.46	840
Twin rows	AF2	53.27	25.14	670
	AF6	53.34	24.3	785
	MONVISO	53.87	22.81	840

Percentage of moisture, percentage of bark and bulk density

SRC before the harvesting (2007)

Single row after the felling (2008)

Average weight
(kg per tree)

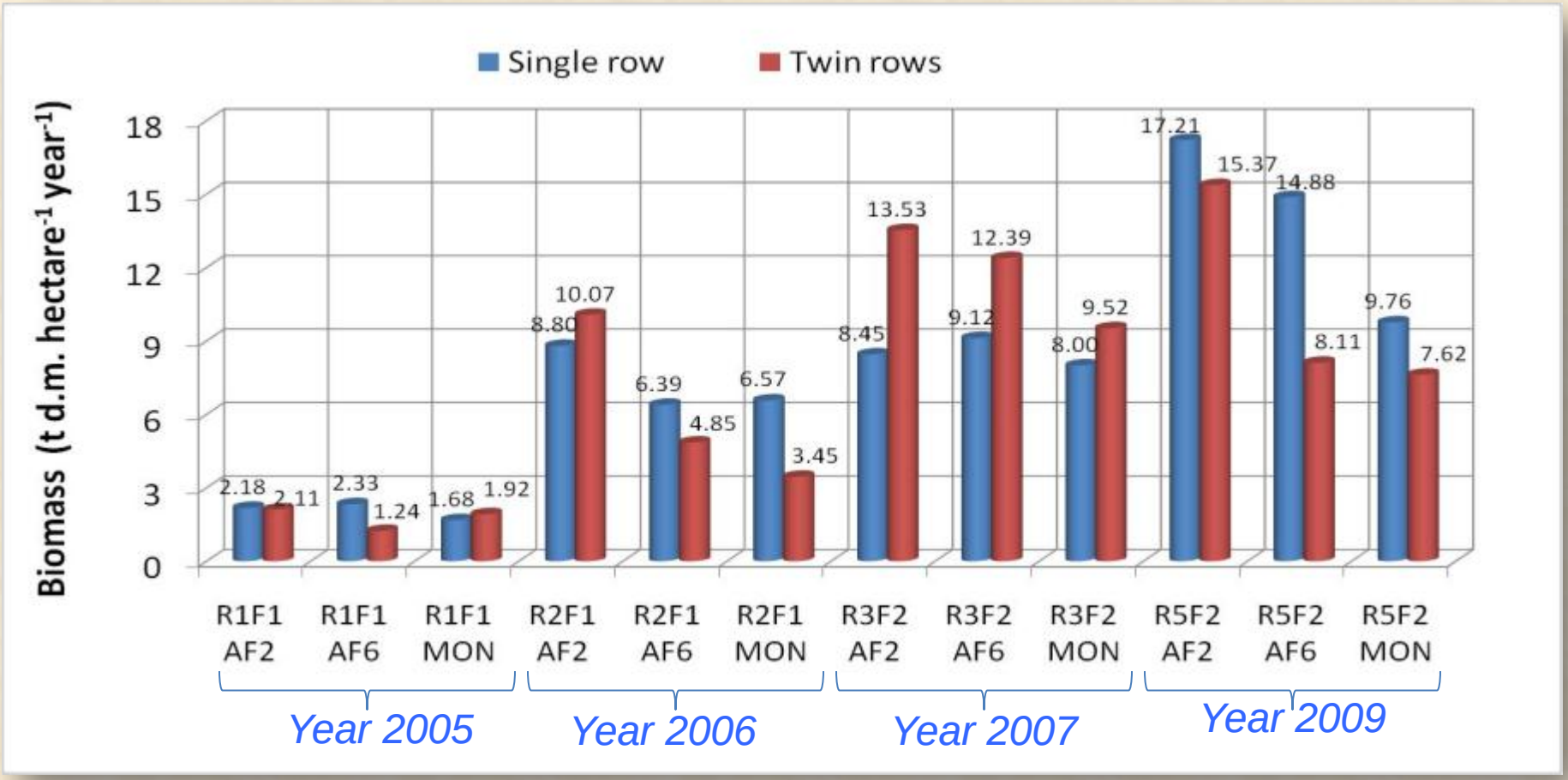
Single row	***R3F2***	***R5F2***
AF2:	1.26	3.05
AF6 :	1.24	3.10
Monviso:	1.34	2.82

Twin rows	***R3F2***	***R5F2***
AF2:	1.97	3.07
AF6:	2.10	2.25
Monviso:	2.31	2.20

Plant typology	Clone	Equations of the weights (y, in kg; x in cm)
Single row	AF2	$y = 0.2523x^{1.9417}$ n = 30 $R^2 = 0.8395$
	AF6	$y = 0.1705x^{2.2471}$ n = 30 $R^2 = 0.8356$
	MONVISO	$y = 0.136x^{2.5201}$ n = 30 $R^2 = 0.9616$
Twin rows	AF2	$y = 0.2187x^{2.0125}$ n = 30 $R^2 = 0.9203$
	AF6	$y = 0.1888x^{2.1929}$ n = 30 $R^2 = 0.6346$
	MONVISO	$y = 0.3359x^{1.8445}$ n =30 $R^2 = 0.9038$

Equations to calculate the weight of the tree as a function of the DBH

BIOMASS PRODUCTION



Plantation productivity at different vegetative seasons per single row and twin rows (years: 2005-2009).

Average productivity
(t d.m. hectare $^{-1}$ year $^{-1}$)

10.02 (year 2007)

12.16 (year 2009)

COSTS ANALYSIS OF THE SRC

The costs are recorded for three years of activity and esteemed up to 11 years of plantation life (*values in €*)

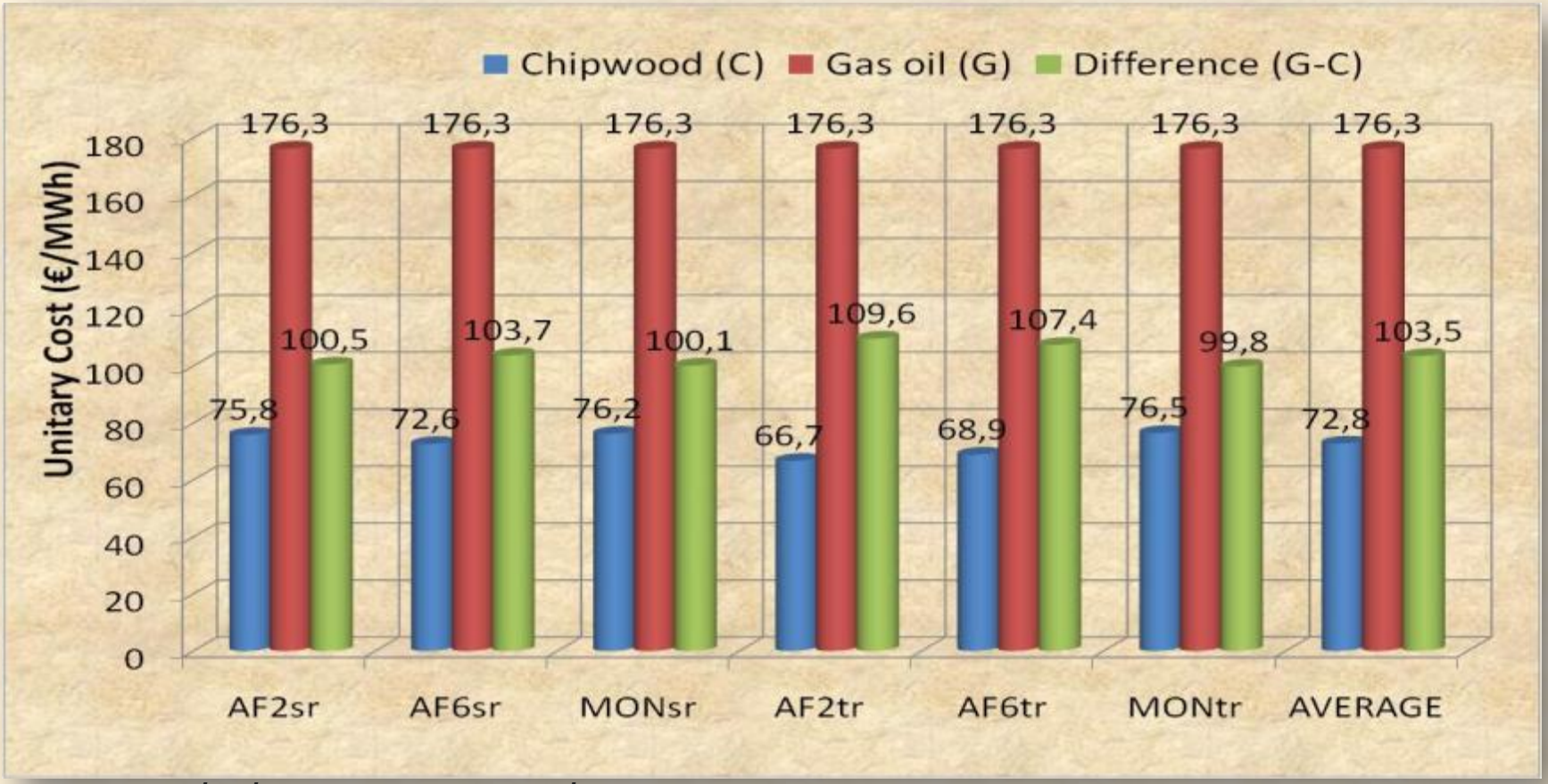
OPERATIONS	*SINGLE ROW*			*TWIN ROWS*		
	AF2	AF6	MON	AF2	AF6	MON
Preparation of the field and planting *Deep scarification, light ploughing, fertilization, harrowing, purchase cuttings and mechanized transplantation*	2,530			3,460		
1st year - Plantation management *Chemical weeding post-planting, nitrogenous fertilization, hoeing (n. 2), irrigation (n. 1), cut back of the stump*	830			850		
2nd year - Plantation management Hoeing (n. 2), manual harrowing	390			400		
3rd-5th-7th-9th-11st year - Plantation management and harvesting *Trees felling and trees stacking to the border of the field. Chipping (in a following phase)*	900			1,125		
4th-6th-8th-10th year - Plantation management *Nitrogenous Fertilization (N), hoeling (n.2)*	280			250		
11st year - Ground restoration Stump grinding with a forest grinder	300			300		
Actualized cost on 11 years cycle (€) *	**8,504.53**			**10,283.52**		
Average production cost (t hectare^{-1} year^{-1}) *	**919.15**			**1,111.42**		
Average production (t hectare^{-1} year^{-1})	**15.86**	**17.52**	**15.63**	**26.32**	**24.14**	**18.76**
Average moisture content (%)	**51.56**	**52.68**	**53.48**	**53.27**	**53.34**	**53.87**
Average chipwood cost (€ per green t)	**57.96**	**52.46**	**58.79**	**42.22**	**46.04**	**59.24**
Average chipwood cost (€ per t, moisture 30%)	**82.80**	**74.94**	**83.99**	**60.32**	**65.77**	**84.63**

** Interest rate = 3%*

ECONOMIC COMPARISON

between the two heating systems

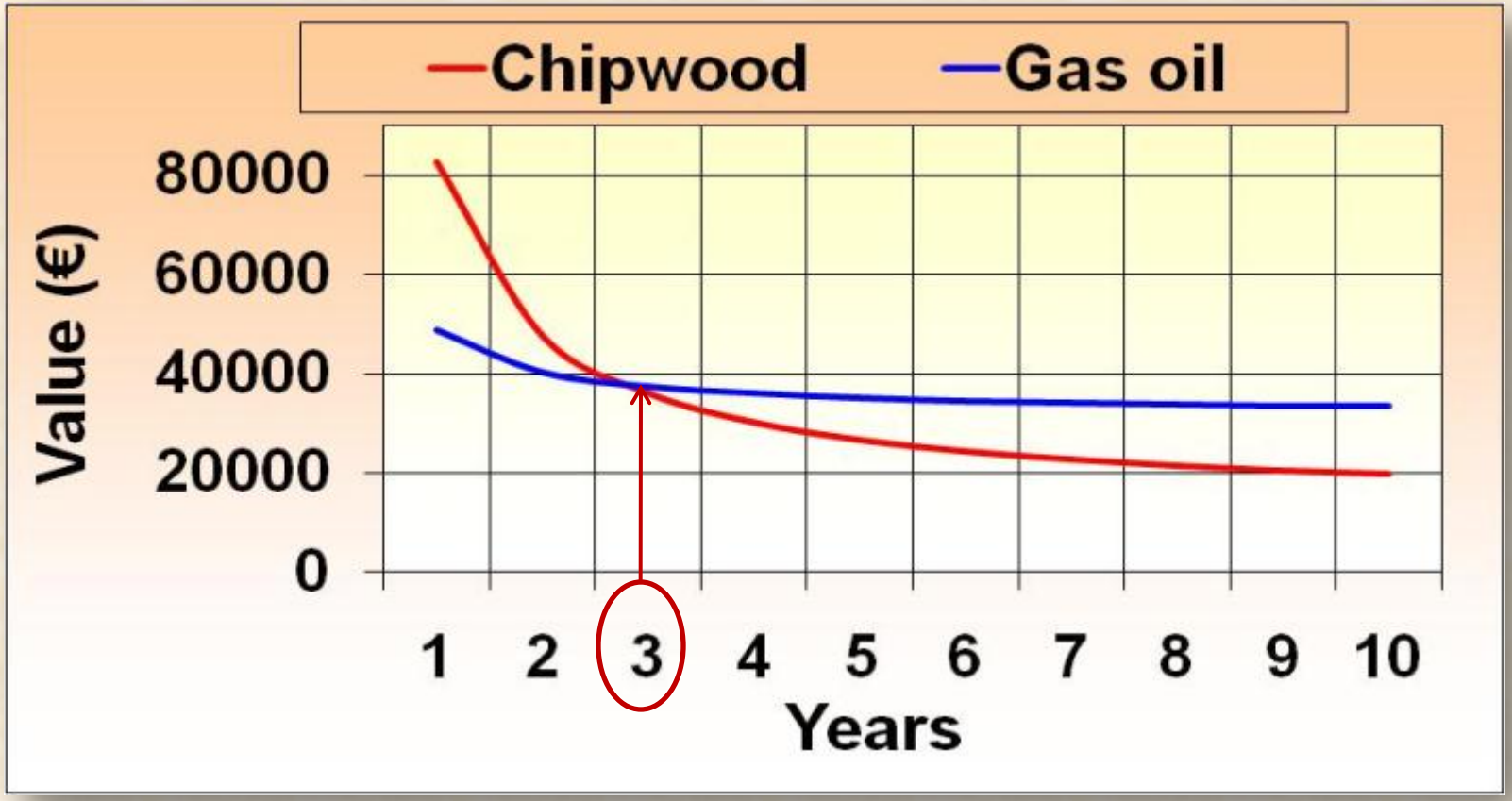
The comparison shows that the chipwood system (thermal power of the boiler 232 kW) is more profitable than the gas oil system. The production cost of 1 thermal MWh is different in relationship with the chipwood production cost for the differents clones (more productivity, less costs)



sr *= single row* ***tr*** *= twin rows*

MICRO-CHAIN: ECONOMIC SUSTAINABILITY

Comparison, in financial terms (interest rate 3%), of the average yearly cost of the two heating systems in the first 10 years of activity

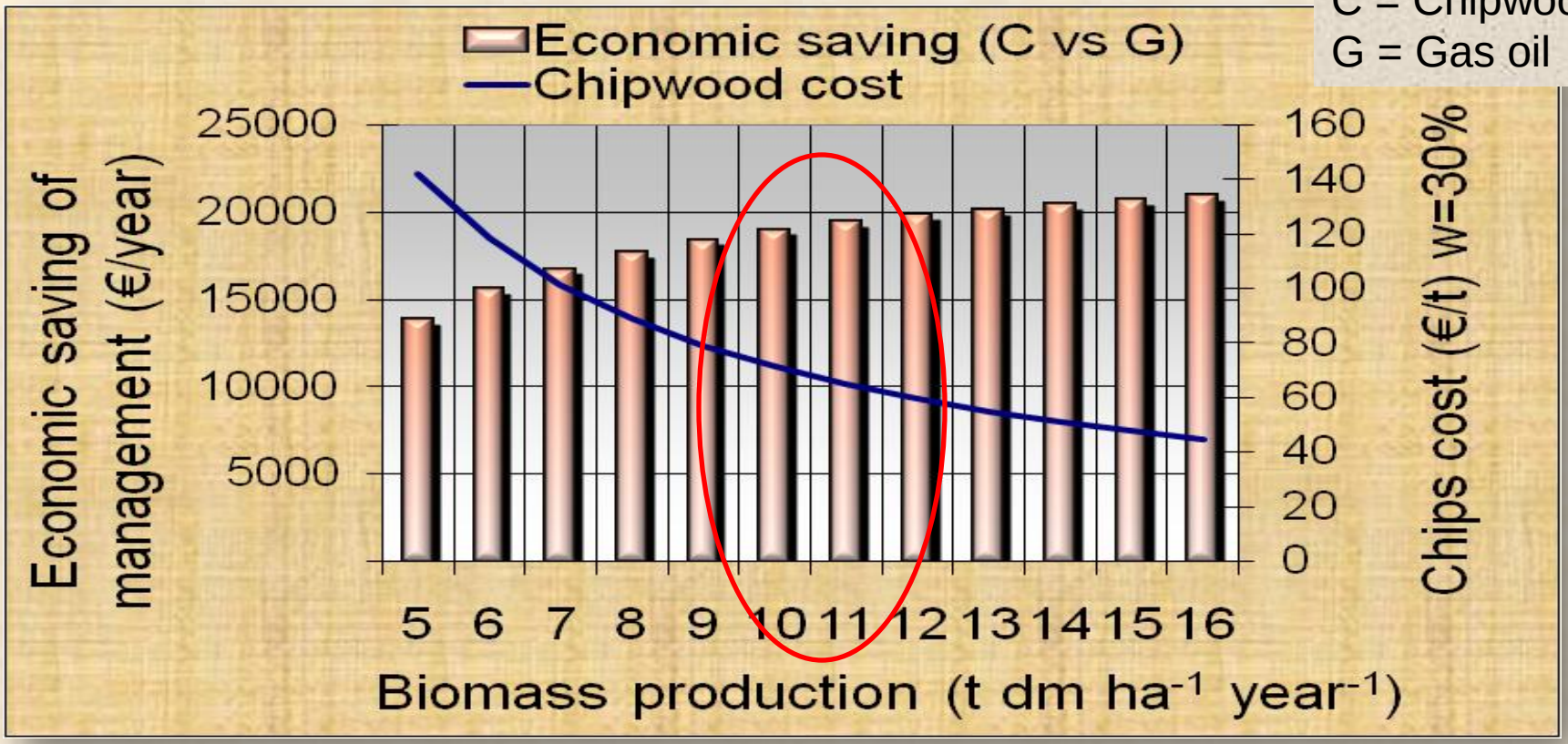


Starting from the 3rd year the chipwood system resulted to be more convenient than the gas oil system

MICRO-CHAIN: ECONOMIC SUSTAINABILITY

The general results underline the economic sustainability of the micro-chain also for non optimal productions of biomass - the total economic advantage of the biomass heating system remains in firm.

C = Chipwood
G = Gas oil



In the case study of the CRA-ING, the heating with biomass boiler approximately involves an economic saving of 17-19,000 € per year (more than 100 € per thermal MWh producted), in comparison to the gas oil system

ENERGETIC BUDGET

Methodology GER - *Gross Energy Requirements*

Energetic index = *output/input*

output = energy to release from wood combustion.
HHV (*Higher Heating Value*) = 20.45 MJ kg^{-1} d.m.

input = energy necessary at the productive cycle

direct: fuel and lubricant used in the productive cycle

indirect: energetic materials value of machines and equipments

Fuel type	*Input (MJ kg^{-1})*
Gas oil	51.5
Petrol	55.3
Lubricant	83.7

Raw material	*Middle energetic contents (MJ kg^{-1})*
Ferrous material	67.5
Not ferrous material	90.0
Light alloys	360.0
Other material	112.5

ENERGETIC BUDGET

Energetic analysis of all productive cycle of SRC (GJ ha $^{-1}$)

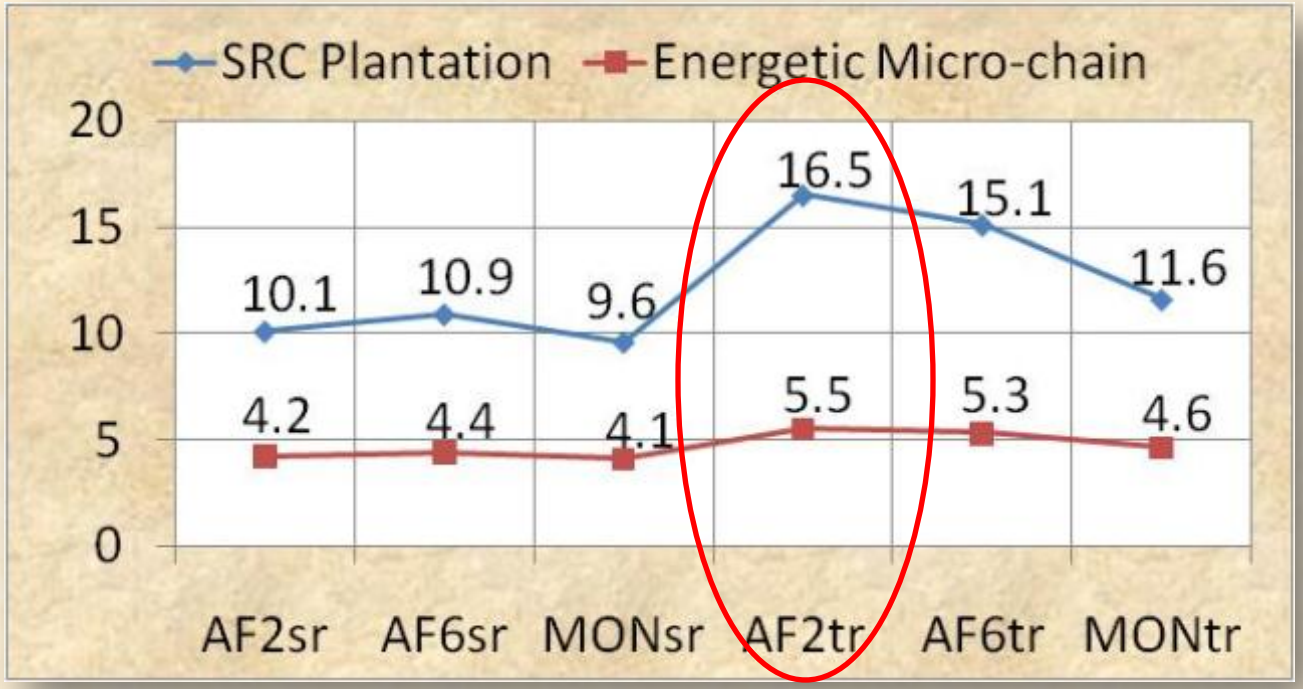
Operation	Direct Input		Indirect Input		Total Input		Output					
	Hypothesis		*Hypothesis*		*Hypothesis*		*Hypothesis*					
	1, 2, 3	*4, 5, 6*	*1, 2, 3*	*4, 5, 6*	*1, 2, 3*	*4, 5, 6*	*1*	*2*	*3*	*4*	*5*	*6*
Preparation of the field and planting	14.1	13.8	5.4	5.2	19.5	19.0	0	0	0	0	0	0
Plantation management 1th year	4.9	2.1	0.7	0.7	5.6	2.7	0	0	0	0	0	0
1th cutting cycle	19.4	19.4	9.0	9.0	28.4	28.4	345.6	373.0	327.2	553.4	506.8	389.4
2nd cutting cycle	19.4	19.4	9.0	9.0	28.4	28.4	345.6	373.0	327.2	553.4	506.8	389.4
3rd cutting cycle	19.4	19.4	9.0	9.0	28.4	28.4	345.6	373.0	327.2	553.4	506.8	389.4
4th cutting cycle	19.4	19.4	9.0	9.0	28.4	28.4	345.6	373.0	327.2	553.4	506.8	389.4
5th cutting cycle	19.4	19.4	9.0	9.0	28.4	28.4	345.6	373.0	327.2	553.4	506.8	389.4
Stump grinding	3.9	3.9	0.3	0.3	4,2	4,2	0	0	0	0	0	0
TOTAL	**120.0**	**116,8**	**51.2**	**50.9**	**171.1**	**167.7**	**1,728.0**	**1,865.0**	**1,636.0**	**2,766.9**	**2,533.8**	**1,946.8**

*(**1**: clone AF2, single row; **2**: clone AF6, single row; **3**: clone Monviso, single row; **4**: clone AF2, twin rows; **5**: clone AF6, twin rows; **6**: clone Monviso, twin rows).*

ENERGETIC BUDGET

Energetic Index Analysis

Output/Input Index of the various poplar clones has satisfactory value in relationship to the plantation and to the energetic micro-chain.



In the first case (plantation), the value is variable between **9.6** and **16.5**. In the second one (energetic micro-chain), the index is lower, but it's still positive varying between **4.1** and **5.5**.

sr *= single row* ***tr*** *= twin rows*

The best results are referred to the **AF2** clone in **twin rows** (referred to R3F2).

CONSIDERATIONS

- The technical results obtained during the period 2005-2009 underline an increasing productivity of the plantation. The biomass production is sustainable into the energy micro-chain because approximately it's possible to obtain **10-12 t d.m. hectare^{-1} year^{-1}**
- The economic and energetic results underline the sustainability of own consumption micro-chain also when the biomass productivity of the SRC plantation is low
- The heating of the building of Agricultural Engineering Research Unit with the chipwood system, in substitution of the gas oil system, on average produce an **economic saving of 18,700 € per year** (**103 € per thermal MWh**)
- The average of the energetic Output/Input index is satisfactory: **12.3 for the SRC plantation** and **4.7 for the energetic micro-chain**
- The productivity of SRC plantation and the energetic efficiency show that it's possible to feed the new thermal boiler (power 232 kW) employing the chipwood produced by **5-8 hectares of SRC** (the variation of surface depends on employed poplar clone)

Thank you for your attention!

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