Economic feasibility of CHP facilities fuelled by biomass from unused agriculture land: case of Croatia

Pfeifer, Antun[1]; Dominković, Dominik Franjo[2];
Ćosić, Boris[1]; Duić, Neven[1]

[1]International Centre for Sustainable Development of Energy, Water and Environment Systems – SDEWES Centre, Zagreb, Croatia

[2]Technical University of Denmark, Department of Energy Conversion and Storage, Frederiksborgvej 399, DK-4000 Roskilde, Denmark

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No 608622.
The sole responsibility of this publication lies with the author. The European Union is not responsible for any use that may be made of the information contained therein.

What will be presented:

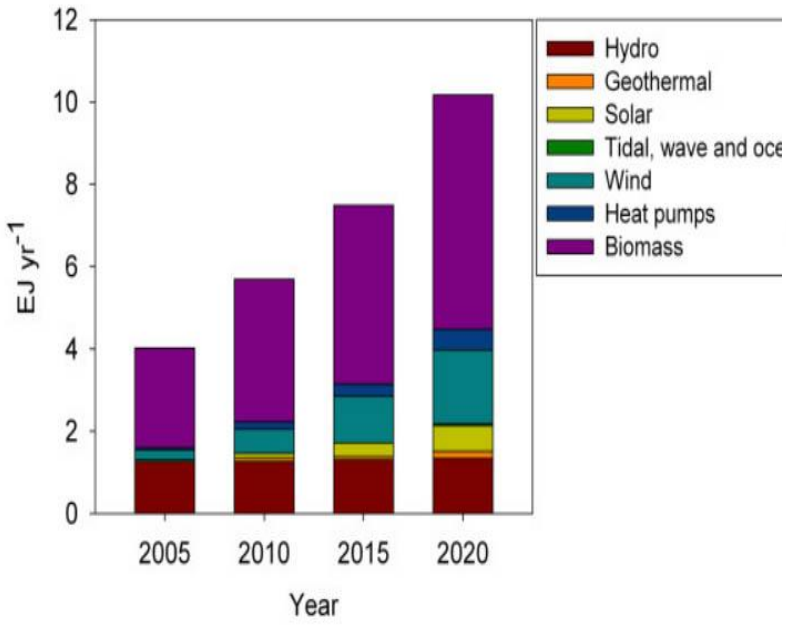
- Introduction
- Unused agricultural land in Croatia
- Short rotation coppice in EU
- Methodology
- Biomass potential from SRC in Croatia
- Macro-location optimization for biomass powered CHP with economic feasibility
- Conclusion

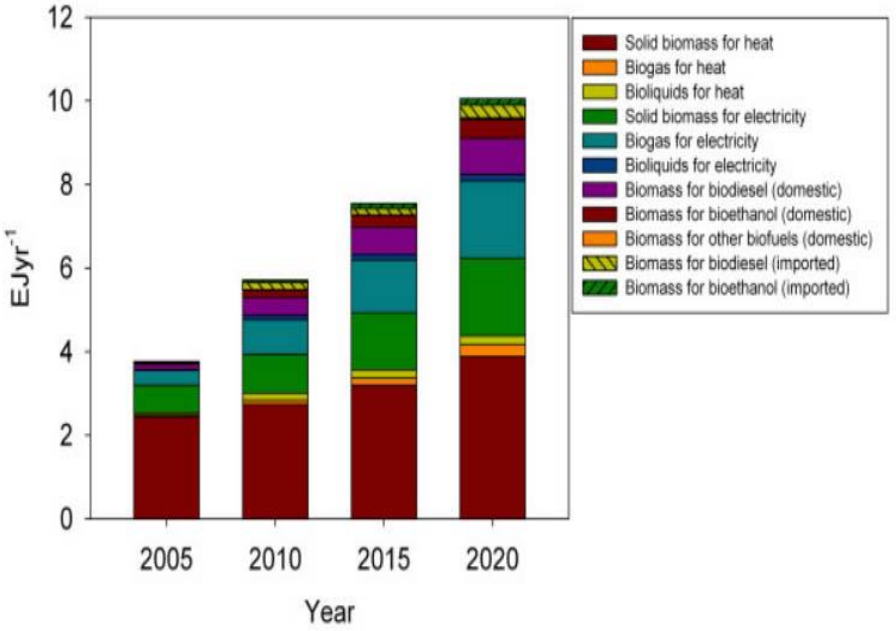
Introduction

- Large areas of agriculture land remains uncultivated in Croatia, both private and state owned,
- At the same time – large unemployment,
- In order to achieve EU goals (20-20-20) and boost economy, new, „green” investments should be encouraged,
- Better governance of resources with the aim of sustainable development is a chance and the way to move forward,
- National action plan for RES (2013.) is oriented towards the use of biomass.

Introduction

- **Directive 2009/28/EC – Member States need to provide National Renewable Energy Action Plan (NREAP)**
  - Explain how MS expect to meet its 2020 targets
  - Including technology mix and the trajectory to reach it





Source: Biomass for energy in the European Union - a review of bioenergy resource assessments

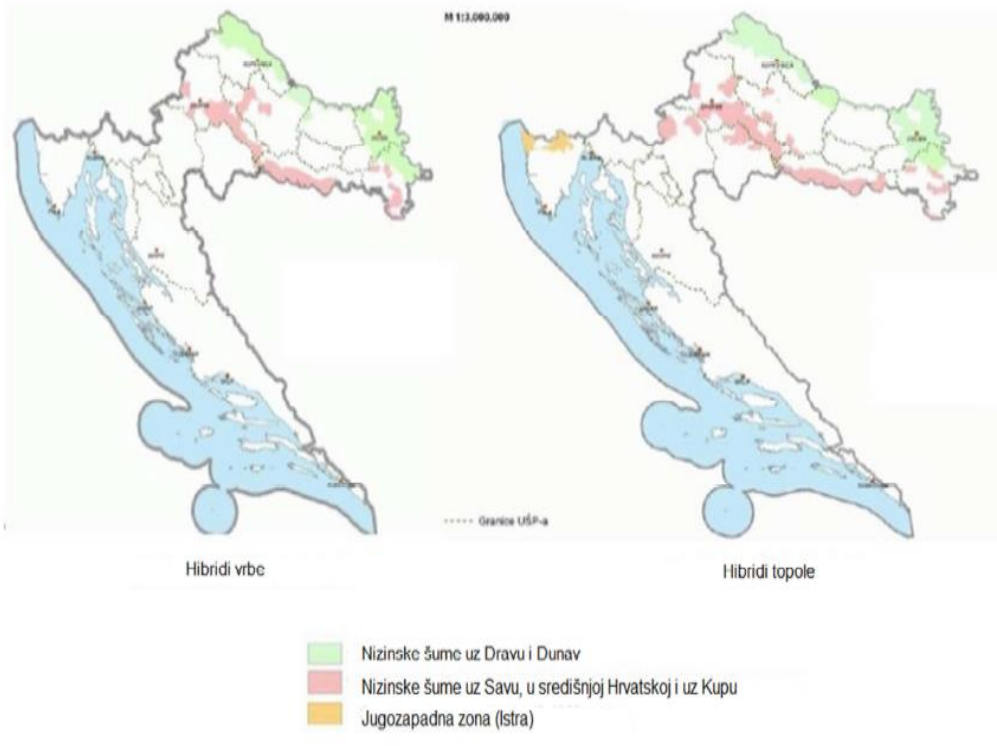
Introduction

- Croatia - Directive 2009/28/EC transposed into national legislation
  - NREAP has been prepared with high emphasises on wind and biomass
- New Low Carbon Development Strategy encourage:
  - Investment cycle
  - Growth of industrial production
  - Competitiveness of the economy
  - Creating jobs with a sustainable perspective

Technology	Energy strategy 2009 - 2020 goals	NREAP - 2020 Goals	Modified NREAP 2020 Goals	RES FIT - in operation 2016	RES FIT - only contract 2016	LCDS - 2020 Goals	LCDS - 2030 Goals	LCDS - 2050 Goals
	[MW]	[MW]	[MW]	[MW]	[MW]	[MW]	[MW]	[MW]
Photo Voltaic	45	52	56	42,98		56	250-350	600-2300
Wind energy	1200	400	744	339,25	404,7	744	1200-2000	3100-3600
Small hydro	100	100	35	2,987	4,932	35	100-140	100-140
Biomass and waste	140	85	120	24,585	94,757	120	150-200	150-280
Biogass		40	70	26,434	34,034	70	80-100	80-120
Geothermal	20	50	30		10	30	30-40	30-50

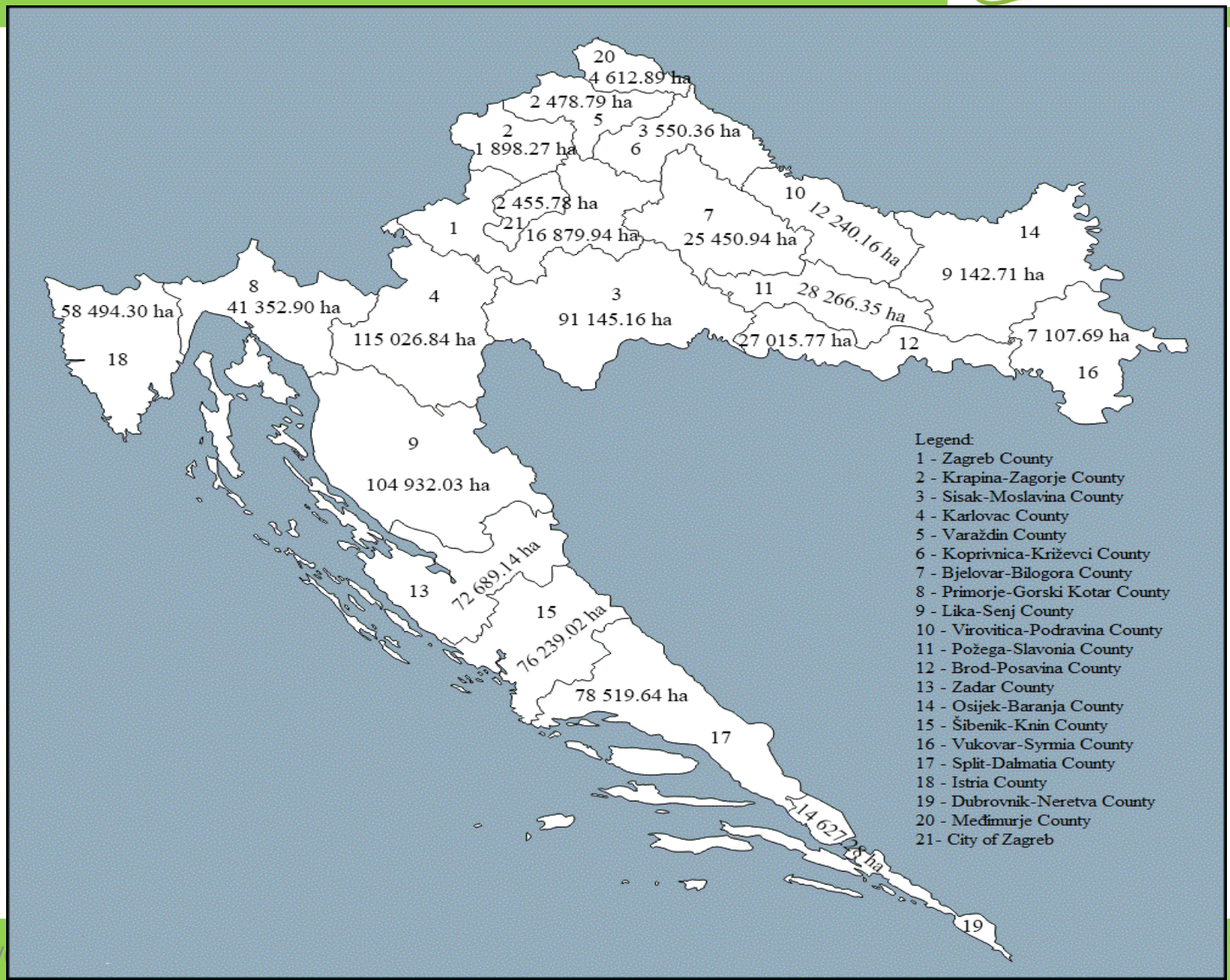
Introduction - Motivation for research

- Large areas of agriculture land remains uncultivated in Croatia, both private and state owned and at the same time high import of food and high unemployment rate (cca 350 000 ha in selected counties)
- Croatia already have willow and poplar



County	Public [ha]	Private [ha]
Krapinsko-zagorska	115	1,783
Varazdinska	1,010	1,469
Medjimurska	1,703	2,910
Koprivnicko-krizevacka	2,563	987
Osjecko-baranjska	3,827	5,316
Vukovarsko-srijemska	4,446	2,662
Viroviticko-podravska	7,019	5,221
Zagrebacka	7,990	8,890
Bjelovarsko-bilogorska	9,975	15,476
Pozesko-slavonska	15,391	12,875
Brodsko-posavska	19,690	7,326
Karlovacka	32,768	82,259
Sisacko-moslavacka	33,733	57,412

Introduction – Motivation for research



Short Rotation Coppice (SRC)

- Short rotation coppice – perennial plants with harvest every 2-8 years and possible use as basic fuel or in co-combustion
- For different climate and soil conditions, different species are feasible

Willow

Poplar

RCG

Hemp

Miscantus

... other...

Short Rotation Coppice (SRC)

In EU countries such as Sweden, Spain, Italy, Finland, and recently also in Germany, France, Great Britain and Ireland, commercial cultivation and exploitation.

	Willow [ha]	Poplar [ha]	Miscanthus [ha]
AT	220-1100	880-1100	800
BE	60		120
DK	5697	2807	64
FR	2300		2000-3000
DE	4000	5000	2000
IE	930		2200
IT	670	5490	50-100
LT	550		
PL	5000-9000	300	
SE	11000	550	450
UK	1500-2300		10000-11000

In Croatia, only experimental fields, 30 ha of willow and poplar.

State support programmes were developed in Sweden, Finland, Italy and Spain.

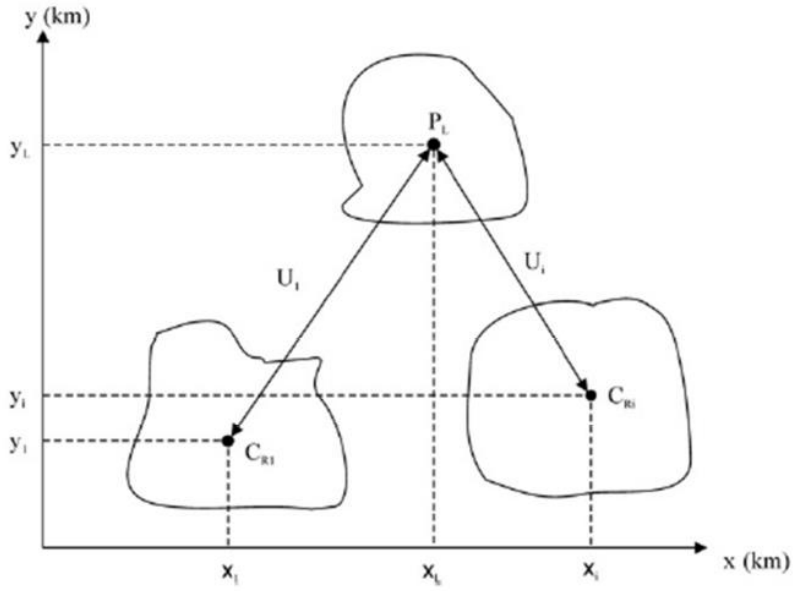
Methodology

Technical potential of respective county or region is calculated:

$$\sum_{n=1}^{n} \mathrm{B}_{teh}\ (\mathrm{n}) = \sum_{n=1}^{n} (\mathrm{A}(n) * \mathrm{P}_y(\mathrm{n}) * k + \mathrm{A}_f(\mathrm{n}) * \mathrm{P}_f(\mathrm{n}))$$

$$\mathrm{B}_{ep(n)} = \mathrm{B}_{teh(n,SRC)} * \mathrm{Hd}_{SRC} + \mathrm{B}_{teh(n,fruit)} * \mathrm{Hd}_{fruit}$$

Energy potential



Price of biomass as a function of SRC farm distance from the power plant:

$$\mathrm{C}_{\mathrm{B,E}} = \sum_{i=1}^{n} \frac{[C_B + (T_p \times U_i)] \times K_{Bi}}{P_B}$$

Cost of biomass:

$$\mathrm{C}_B = \mathrm{T}_S + \mathrm{T}_Z + \mathrm{T}_{O\&M}$$

Scenarios for case study Croatia

- Calculation with assumption of 12 t_{DM}/ha/year biomass yield
- State owned, private owned and aggregate land is considered separately
- Four scenarios:

S1 – 30 % of land cultivated by SRC

S2 – 20 % of land cultivated by SRC

S3 – 10 % of land cultivated by SRC

S4 – 20 % of land cultivated by combination of SRC and most wide spread fruit sorts in Croatia (apple, pear, peach, cherry, plum, walnut and hazelnut)

In scenarios,
a – public,
b – private,
c – aggregate;
in S4 – a: with 100% fruit compensation,
b: 50%, c:25%

		Total biomass (kg/ha)
FRUIT TREES	Apple	5,571.43
	Pear	5,833.33
	Peach and nectarine	2,921.21
	Apricot	1,619.58
	Cherry (sweet and sour)	1,783.07
	Plum	2,053.15
	Fig	1,281.12
DRY FRUIT TREES	Walnut	538.04
	Hazelnut	1,848.48
	Almond	1,625.17
GRAPE	Total	4,258.37
OLIVE	Total	2,522.22

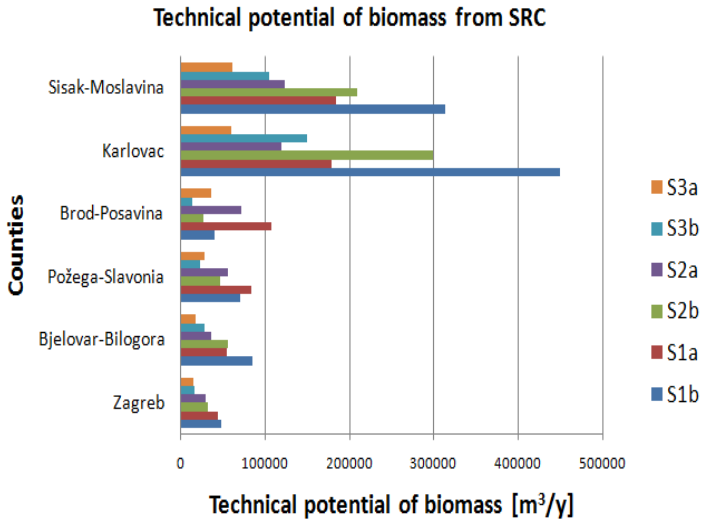
Values used in calculations of scenarios:

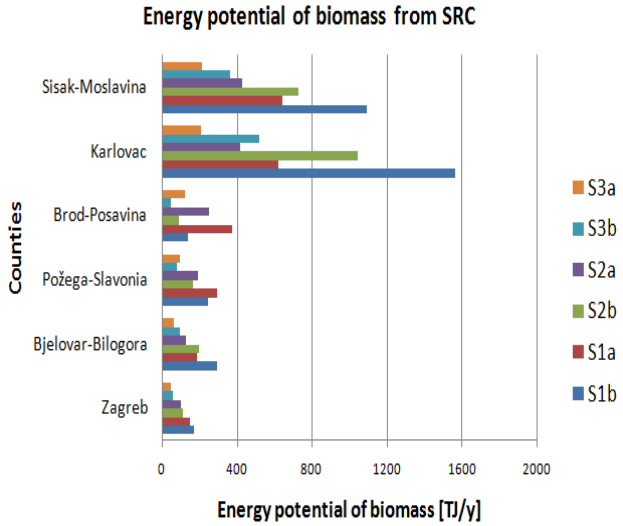
	amount	unit
Power plant availability	0.9	
Biomass price at the SRC field	43.47	€/ton
Lower calorific value (30 % moisture)	3,400	kWh/ton
η power plant total	0.87	
η_{el}	0.29	
HTP ratio	2.00	
η storage	0.8	
Storage temperature	90	^{o}C
Power plant specific investment cost	3,600	€/kW_e
Absorber investment cost	400	€/kW
District system piping cost	5,820	€/dwelling
Dwellings connected to DHC system	8,700	

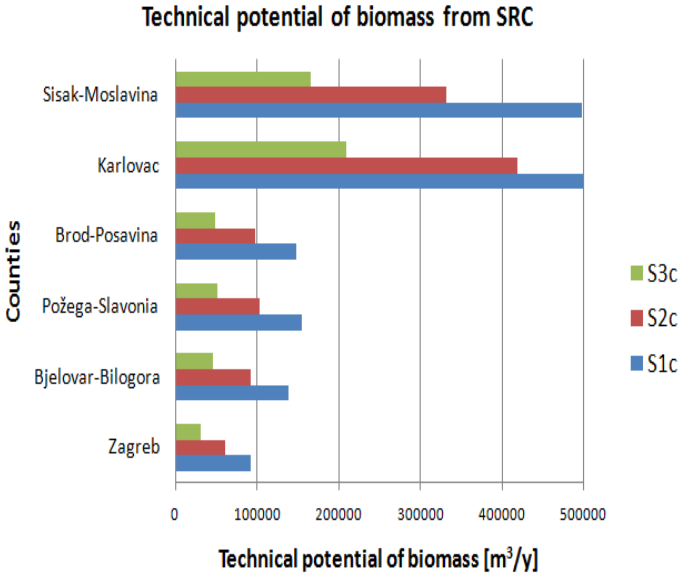
Storage investment cost	56	€/m^3
Plant own electricity consumption	6%	
Discount rate	7%	
Feed-in-tariff	0.122	€/kWh_e
COP	0.7	
Design temperature for heating	21	^{o}C
Design temperature for cooling	26	^{o}C
Fixed power plant O&M cost	29	€/kW per annum
Variable power plant O&M cost	0.0039	€/kWh
District heating O&M cost	75	€/dwelling per annum
Storage O&M cost	0.39	€/m^3 per annum
Heating energy revenue	0.0198	€/kWh
Project lifetime	14	years

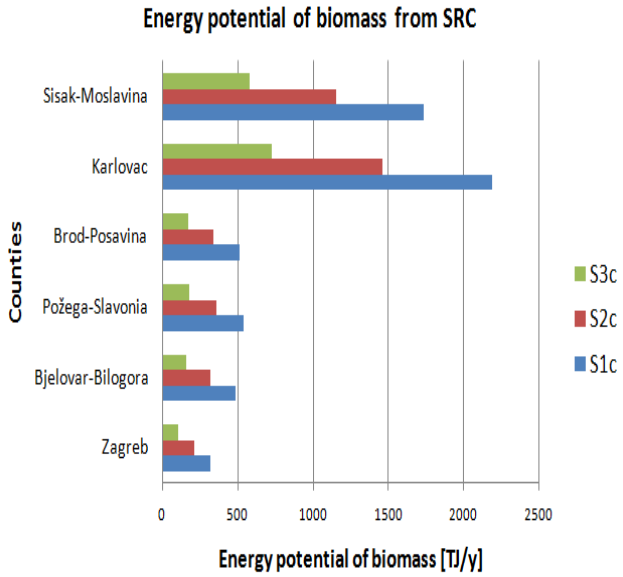
Code source: “A hybrid optimization model of biomass trigeneration system combined with pit thermal energy storage”

Results

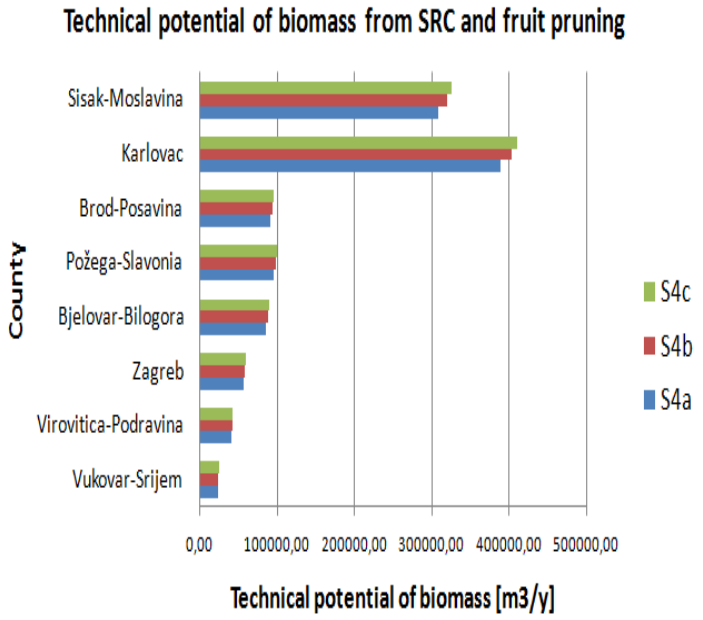

Technical potential of biomass from SRC
Sisak-Moslavina
Karlovac
Brod-Posavina
Požega-Slavonia
Bjelovar-Bilogora
Zagreb
Counties
0
100000
200000
300000
400000
500000
Technical potential of biomass [m3/y]
S3a
S3b
S2a
S2b
S1a
S1b

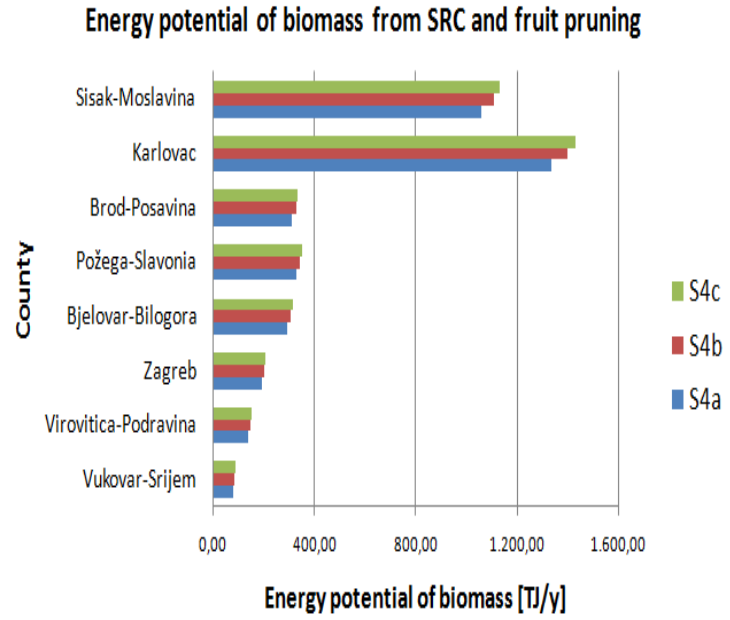

Energy potential of biomass from SRC
Sisak-Moslavina
Karlovac
Brod-Posavina
Požega-Slavonia
Bjelovar-Bilogora
Zagreb
Counties
0
400
800
1200
1600
2000
Energy potential of biomass [TJ/y]
S3a
S3b
S2a
S2b
S1a
S1b


Technical potential of biomass from SRC
Sisak-Moslavina
Karlovac
Brod-Posavina
Požega-Slavonia
Bjelovar-Bilogora
Zagreb
Counties
0
100000
200000
300000
400000
500000
Technical potential of biomass [m3/y]
S3c
S2c
S1c


Energy potential of biomass from SRC
Sisak-Moslavina
Karlovac
Brod-Posavina
Požega-Slavonia
Bjelovar-Bilogora
Zagreb
Counties
0
500
1000
1500
2000
2500
Energy potential of biomass [TJ/y]
S3c
S2c
S1c

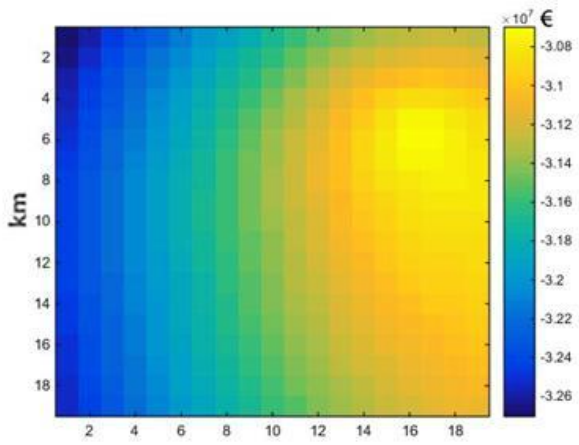
Results



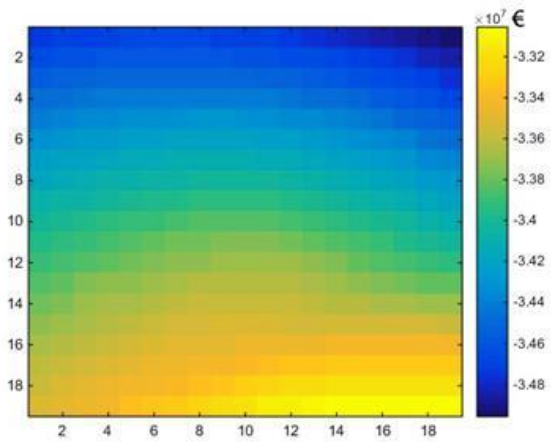


Croatia	Technical potential [m³/y]	Energy potential [TJ/y]
$S1_a$	1,404,094.31	4,902.29
$S1_b$	1,426,108.32	4,979.16
$S1_c$	2,830,202.63	9,881.45
$S2_a$	936,062.87	3,268.20
$S2_b$	950,738.88	3,319.44
$S2_c$	1,886,801.75	6,587.63
$S3_a$	468,031.44	1,634.10
$S3_b$	475,369.44	1,659.72
$S3_c$	943,400.88	3,293.82
$S4_a$	1,169,257.63	4,176.11
$S4_b$	1,212,193.70	4,328.94
$S4_c$	1,233,661.73	4,355.57

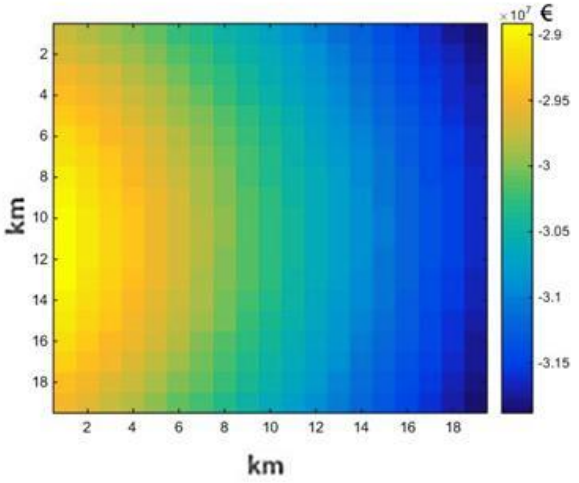
Results of NPV analysis of feasibility of CHP



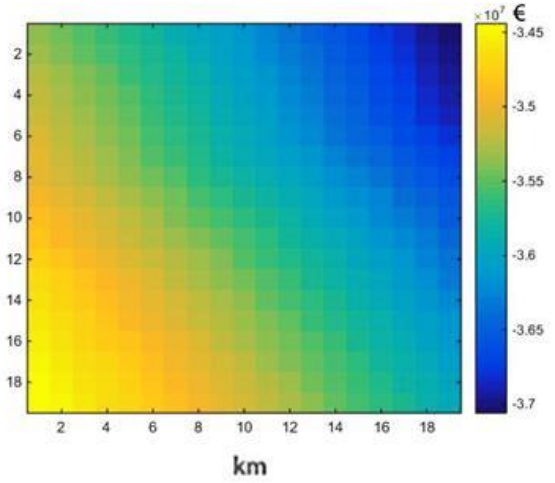
Velika Gorica (NPV = - 30 698 928 €)



Koprivnica (NPV = - 33 055 331 €)



Slavonski Brod (NPV = - 28 915 699 €)



Osijek (NPV = - 34 441 299 €)

NPV of optimal locations at each macro-location for the scenario S1c

Cost of biomass on selected macro-locations:

Location:	Velika Gorica	Koprivnica	Slavonski Brod	Osijek
Scenario:	Cost $C_{B,E}$ [€/t]			
S1a	47.7	51.1	45.9	51.9
S1b	47.6	50.2	48.7	52.3
S1c	46.4	48.7	44.7	50.0
S2a	48.2	52.6	47.7	52.9
S2b	48.0	51.8	51.2	55.0
S2c	47.4	49.7	46.2	51.2
S3a	50.7	55.2	53.3	58.9
S3b	49.3	53.8	55.7	61.2
S3c	48.0	52.2	49.2	53.4
S4a	47.5	49.9	46.4	51.5
S4b	47.4	49.8	46.3	51.3
S4c	47.4	49.7	46.3	51.3

Conclusion

- Over 1 000 000 ha of unused agricultural land in Croatia has great potential for cultivation of SRC, but also to increase cultivated area under most popular fruit sorts
- There is a lot of work ahead to start a commercial cultivation of SRC in Croatia
- SRC has potential to be primary or supporting fuel for CHP, but is still to expensive for most challenging technologies, such as CCHP
- Future work can establish value chains for both types of woody biomass with lower cost

Thank you for your attention !!

Boris.Cosic@fsb.hr




This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No 608622.
The sole responsibility of this publication lies with the author. The European Union is not responsible for any use that may be made of the information contained therein.