BECOOL

Brazil-EU Cooperation for Development of Advanced Lignocellulosic Biofuels

RESULTS FROM FIVE YEARS FOOD AND ENERGY CROP ROTATIONS: FEEDSTOCK QUANTITY AND QUALITY FOR ADVANCED BIOFUEL VALUE CHAINS

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ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA

BECOOL PROJECT AT GLANCE

- **Project title**: Brazil-EU Cooperation for Development of Advanced Lignocellulosic Biofuels
- **Coordinator:** University of Bologna (Prof. Andrea Monti)
- **12 Partners**
- **General objective:** Strenghten the EU-Brazil cooperation on advanced lignocellulosic biofuels
- **Twin Brazilian Projcect:** BioValue (20 Partners)
- **Project duration**: 2017-2022

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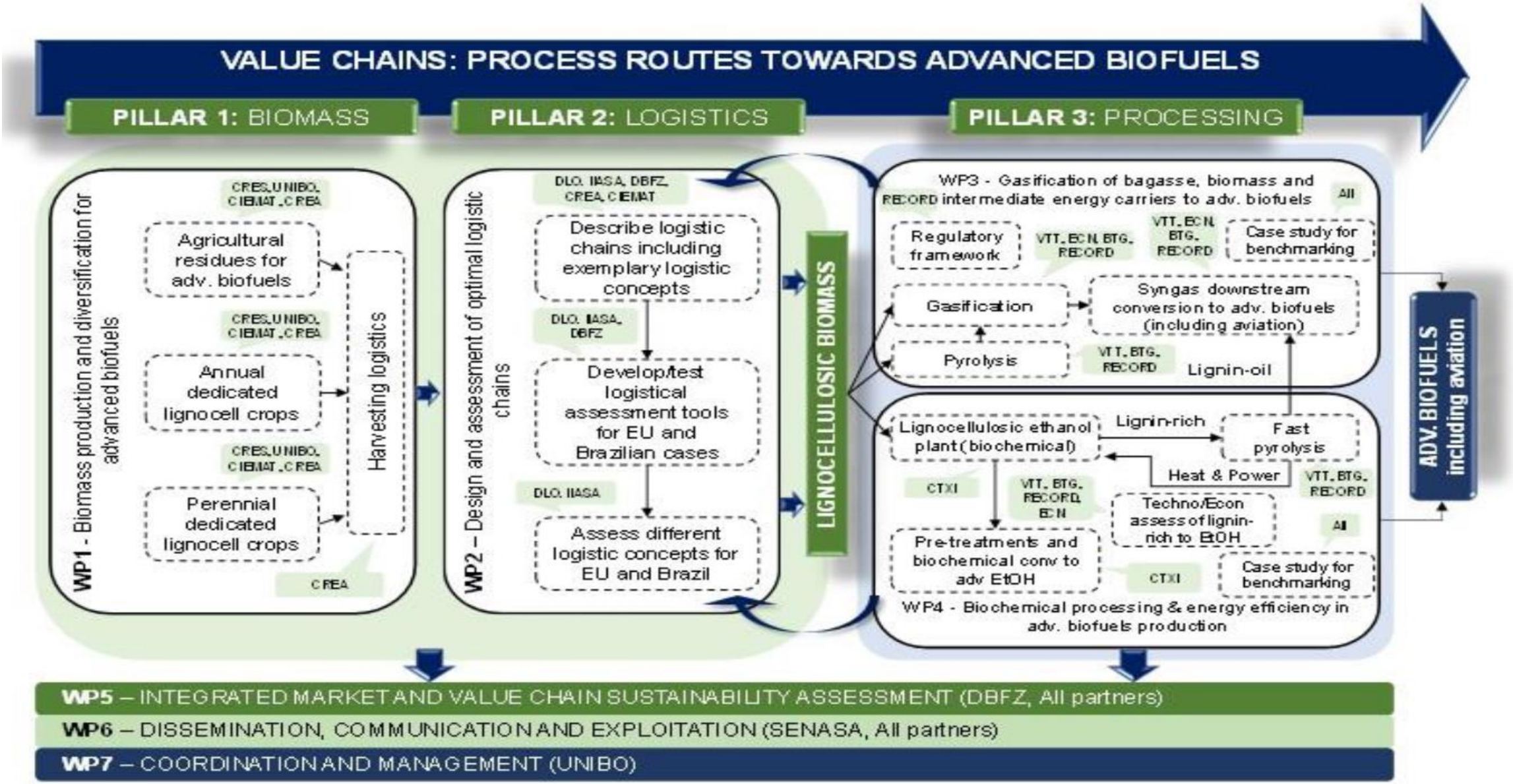
BECOOL workflow



Biomass production and feedstock diversification for advanced biofuels

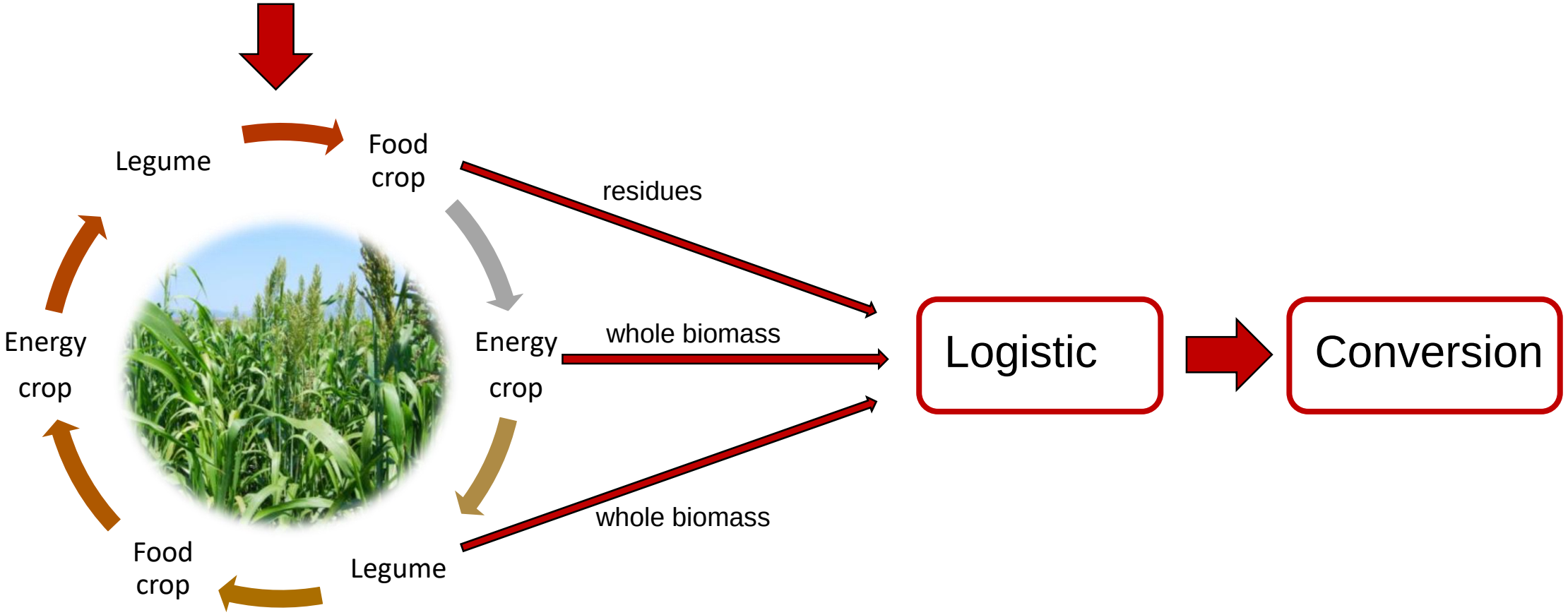
General objective: to produce feedstock for advanced biofuel without reducing food land

How to reach this target???

=> Identifying integrated cropping systems including lignocellulosic and food crops

New cropping schemes: the concept

The today cropping systems could be intensified and diversified including lignocellulosic crops



Potential advantages of innovative cropping systems

1. Enhanced **soil fertility** due to positive rotational effects
2. Production of feedstock **without competing** with food land
3. **Market opportunities** and **reduced** economic **risks** for farmers
4. **Sustainable cropping systems** due to **low inputs** requirements (agrochemicals, fertilizers etc.) to build sustainable chains and **reduce the GHG emissions**
5. **Increase the feedstock** availability (shorten the supply chain and reduce transportation costs)
6. **Increase** the conversion **plant size** thanks to greater feedstock availability
7. Production of multi-feedstock can **avoid shortage** in case of harsh seasons

Challanges of the innovative cropping systems

1. Identify suitable crops
2. New farming systems and machineries
3. Innovative logistic concepts and conversion
4. Sometime unfamiliar crops for farmers

The innovative cropping systems

- The performance of new crops is **quantitatively** and **qualitatively** evaluated

- Field studies are replicated in **Italy**, **Greece** and **Spain**

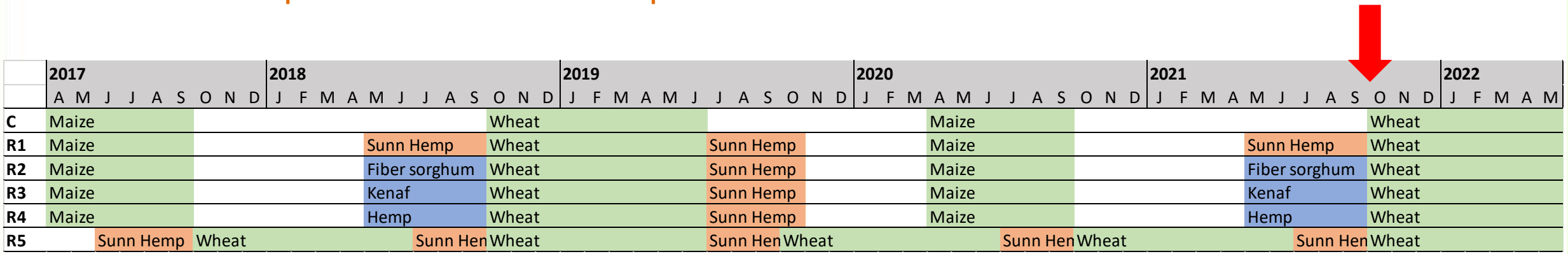
Crop rotation at the experimental farm of the University of Bologna

The innovative cropping systems

The integrated cropping systems including food and lignocellulosic crops are:

C: maize – wheat – fallow – maize (control rotation)
R1: maize – sunn hemp+ wheat – sunn hemp – maize
R2: maize – biomass sorghum+ wheat – sunn hemp – maize
R3: maize – kenaf+ wheat – sunn hemp – maize
R4: maize – hemp+ wheat – sunn hemp – maize
R5: sunn hemp + wheat – sunn hemp+ wheat

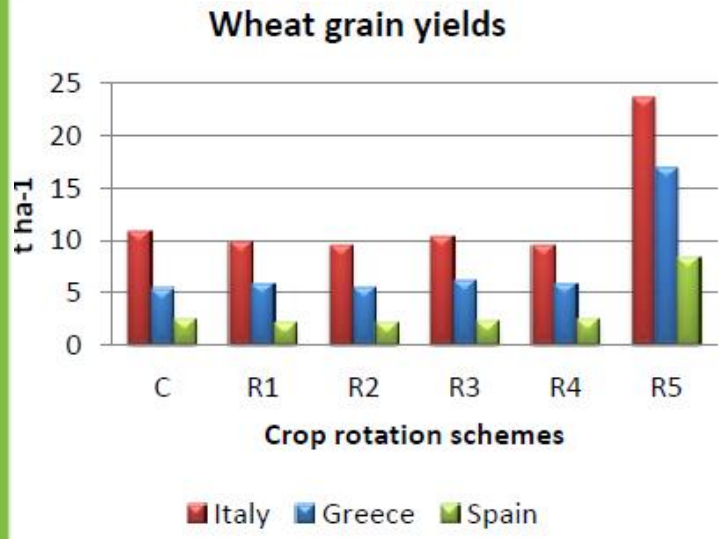
green: food crop
orange: legume
blue: energy crop

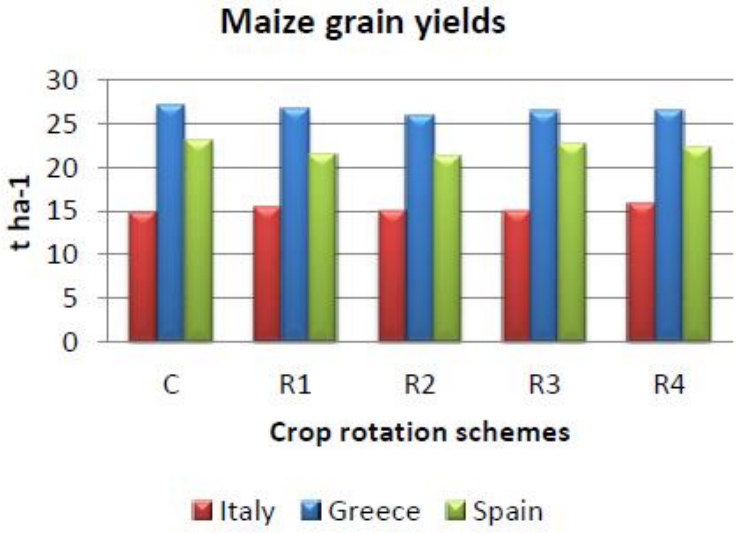


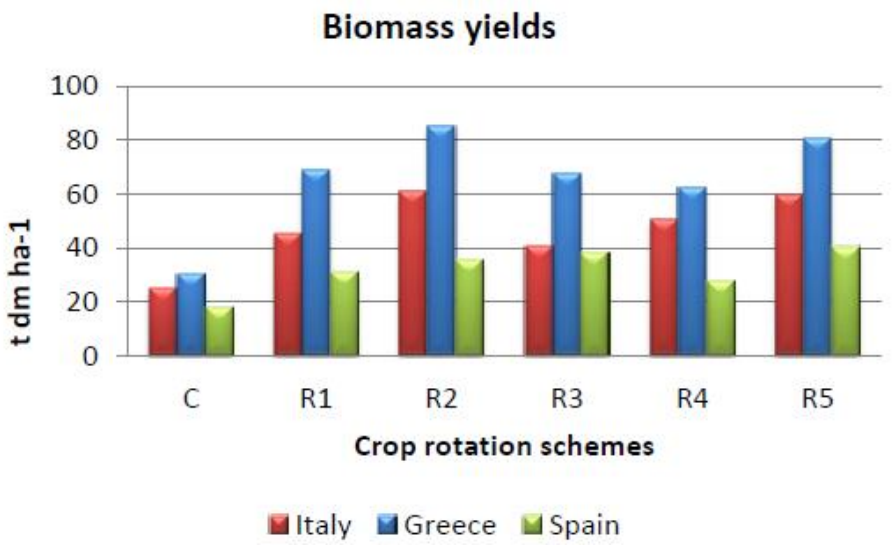
RCBD with 4 reps

Cropping system performance in quantitative terms

	2017									2018										2019										2020										2021				2022					
	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M
C	Maize																		Wheat											Maize															Wheat					
R1	Maize												Sunn Hemp						Wheat						Sunn Hemp						Maize										Sunn Hemp				Wheat					
R2	Maize												Fiber sorghum						Wheat						Sunn Hemp						Maize										Fiber sorghum				Wheat					
R3	Maize												Kenaf						Wheat						Sunn Hemp						Maize										Kenaf				Wheat					
R4	Maize												Hemp						Wheat						Sunn Hemp						Maize										Hemp				Wheat					
R5		Sunn Hemp								Wheat						Sunn Hen			Wheat						Sunn Hen	Wheat						Sunn Hen	Wheat									Sunn Hen			Wheat					



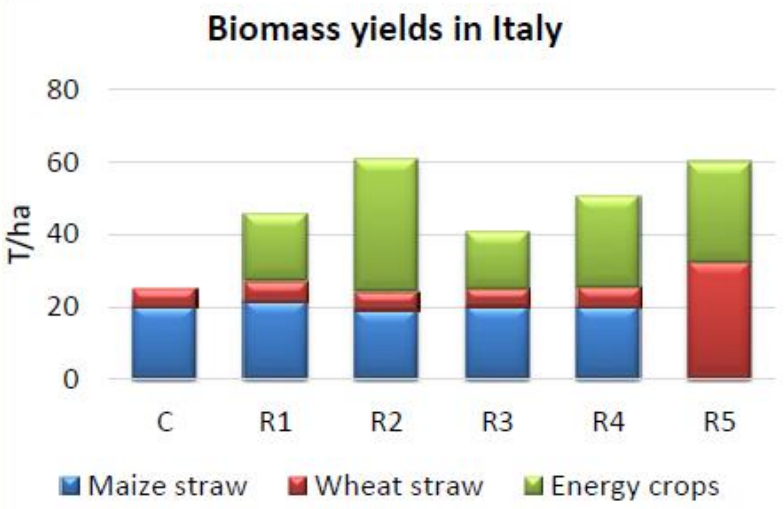


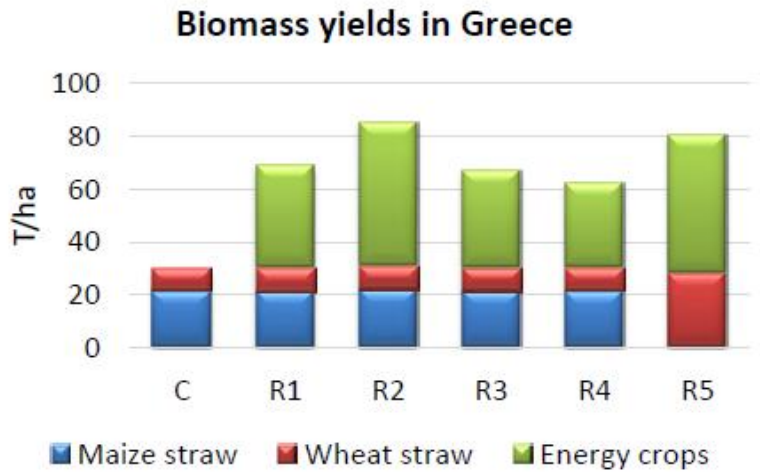


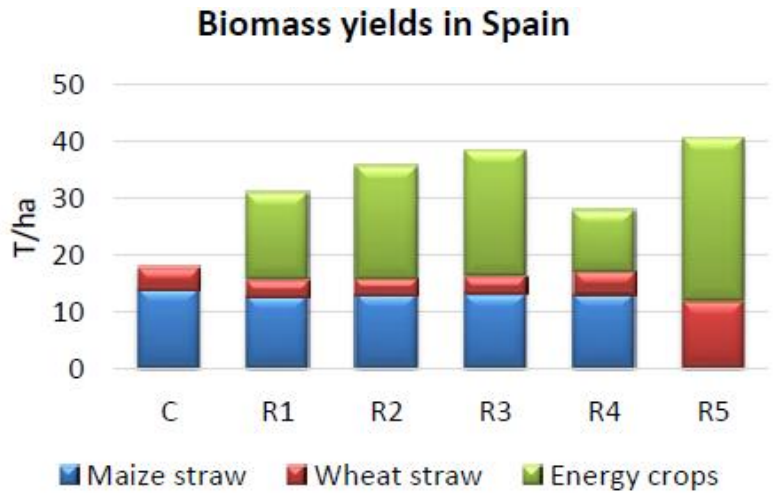
- Wheat grain yields were the highest in the R5 rotation in all environments
- Maize grain yields were not affected by the rotations in all environments
- R2 and R5 rotation resulted in highest biomass yields in all environments
- The observed trend are similar, hence analogous value chains schemes could be replicated in different regions

Cropping system performance in quantitative terms

	2017									2018										2019										2020										2021				2022					
	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M
C	Maize																		Wheat											Maize															Wheat					
R1	Maize												Sunn Hemp						Wheat						Sunn Hemp						Maize										Sunn Hemp				Wheat					
R2	Maize												Fiber sorghum						Wheat						Sunn Hemp						Maize										Fiber sorghum				Wheat					
R3	Maize												Kenaf						Wheat						Sunn Hemp						Maize										Kenaf				Wheat					
R4	Maize												Hemp						Wheat						Sunn Hemp						Maize										Hemp				Wheat					
R5			Sunn Hemp							Wheat						Sunn Hen			Wheat						Sunn Hen	Wheat						Sunn Hen	Wheat										Sunn Hen			Wheat					

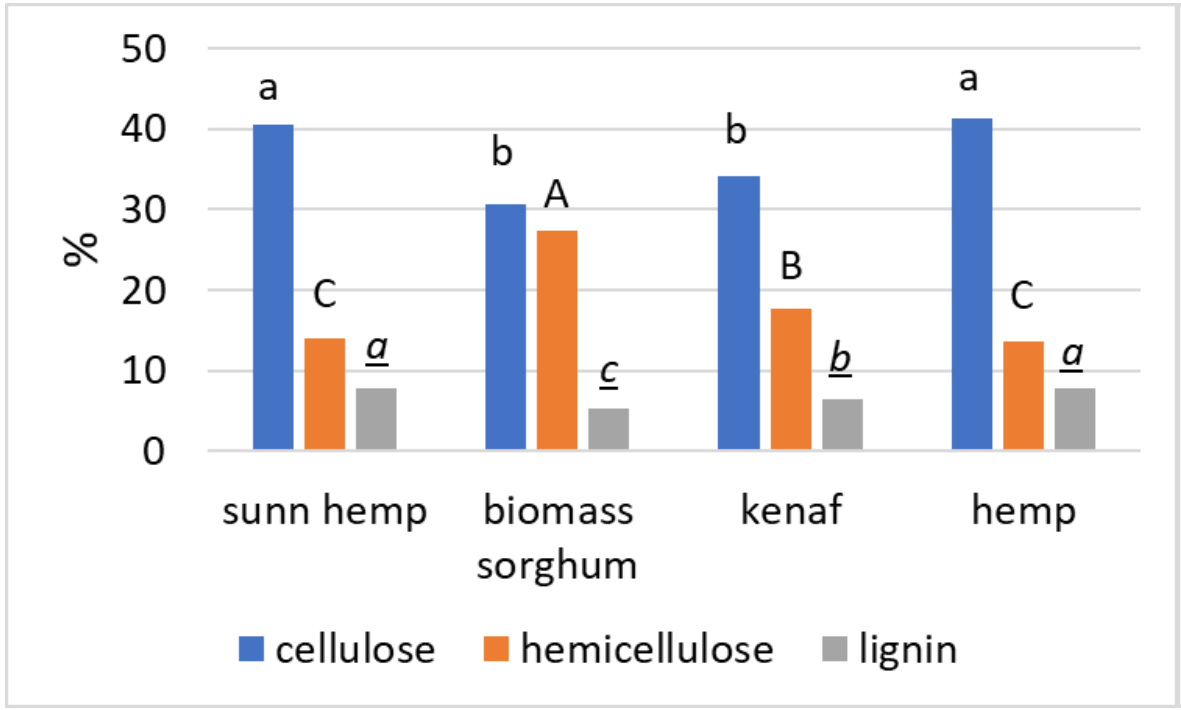


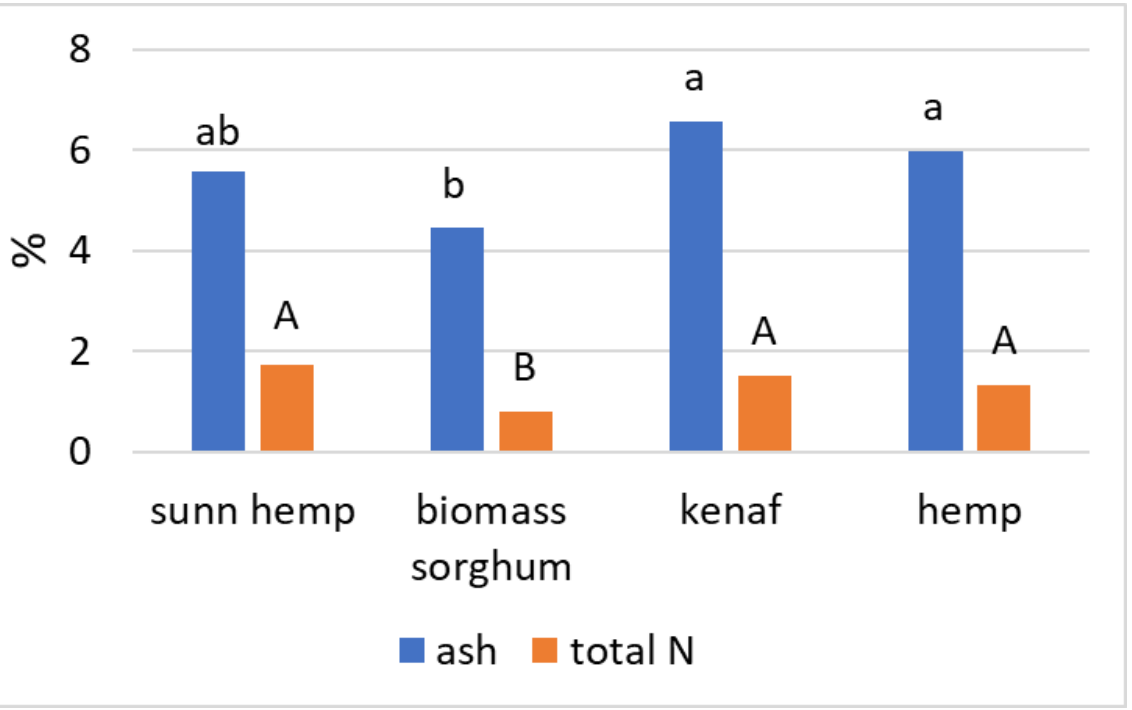




- Biomass yields increased when the energy crops were included in the rotation scheme
- The rotation R5 lead to the overall highest yield. In Italy it was attributed to wheat straw whereas in Greece and Spain it was mainly due to sunn hemp
- Apart from R5, highest yields were also recorded in R2 in Italy and Grecce, and R3 in Spain

Cropping system performance in qualitative terms





Total carbon did not differ among varieties (average 46.5%)

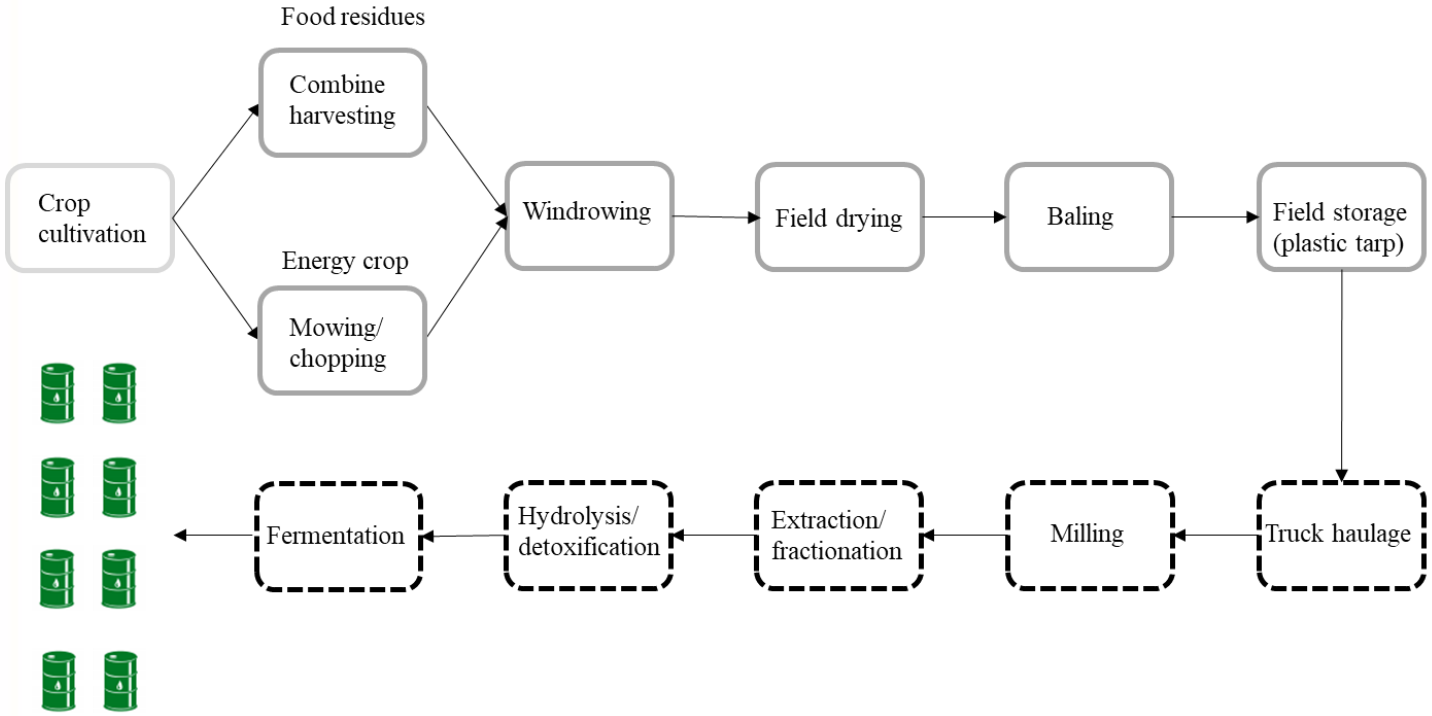
High cellulose and hemicellulose, low lignin, ash and N are desirable characteristics for bio/thermochemical conversion

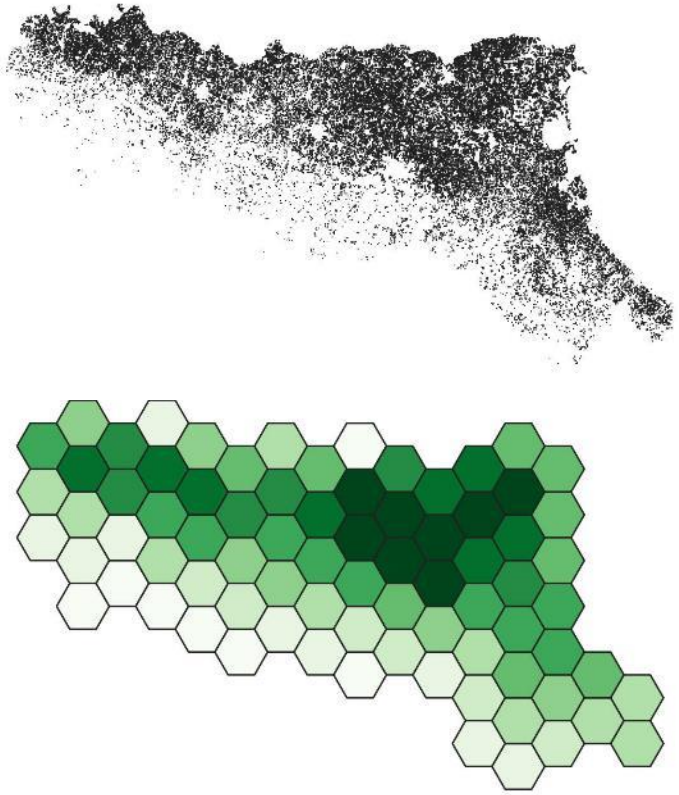
Cropping system performance in qualitative terms

	Al	Ca	Fe	K	Mg	Na	P	S	Si	Si/K	Ca/K
Sunn hemp	28 (a)	7k (b)	43 (b)	10k (a)	2k (b)	233 (ab)	1.5k (b)	1.2k (a)	373 (a)	.037 (a)	.72 (b)
Biomass sorghum	15 (a)	2k (c)	31 (b)	5k (b)	2k (b)	92 (b)	1k (b)	729 (b)	210 (bc)	.042 (a)	.46 (b)
Hemp	43 (a)	11k (ab)	65 (a)	11k (a)	2k (b)	212 (b)	2k (a)	1.2k (a)	150 (c)	.014 (b)	1.02 (b)
Kenaf	29 (a)	13k (a)	43 (b)	7k (b)	3k (a)	392 (a)	1k (b)	1.5k (a)	216 (b)	.033 (a)	1.91 (a)

- Biomass sorghum and hemp have the general lowest and highest mineral concentration, respectively
- Sunn hemp and kenaf show intermediate values
- Inorganic elements (e.g. alkali) produced during combustion may cause a number of serious problems to power plants through slagging, corrosion and fouling

Example of biochemical value chain under evaluation





Design of a BECOOL value chain that the consortium is evaluating in terms of:

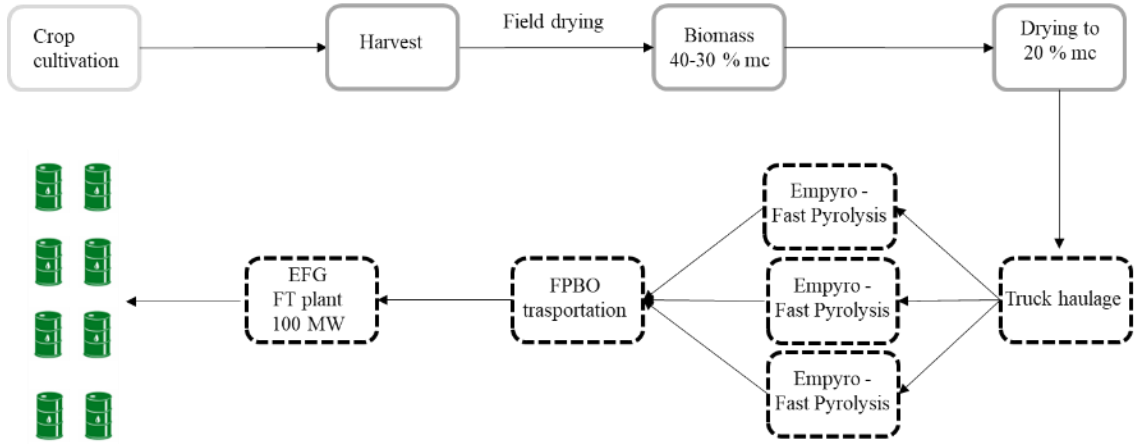
- Yield
- Cost
- Sustainability

Overall EU assessment

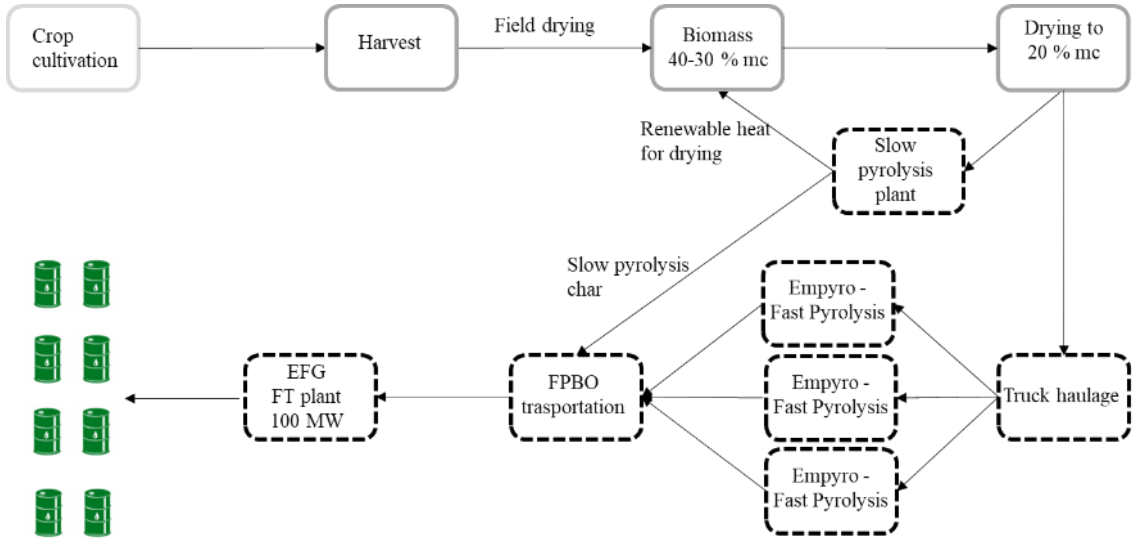
Example of thermochemical value chain under evaluation

Initial Reference Case Study

Fast Pyrolysis (Empyro) followed by Entrained Flow Gasification (EFG)



New Case Study



Conclusions

- **Biomass yields increased** when the **energy crops were included** in the rotation scheme
- **Food** production was **not reduced**
- **Biomass sorghum** is the **most promising annual crops** in terms of quantity and quality (high cellulose and hemicellulose; low lignin, ash, nitrogen and solphur)
- Sunn hemp, kenaf and hemp are suitable to biochemical conversion, whereas pyrolisis test are ongoing. Sunn hemp, in particular, is raising interest for its extremely **low input requirement** and its **nitrogen-fixing** ability.
- **Annual** lignocellulosic **crops** have a **wide land availability**, hence can greatly contributing to the scale up of the value chains
- Result suggests that the **conversion plants will have to be fed by different feedstocks** and should be set up in order to **handle the different biomass compositions**

Thanks for your attention

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