Marginal lands for Growing Industrial Crops

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1 Publishable executive summary

Bio2Match tool is an internet-based tool guiding the user for an optimal match between biomass crops and conversion technologies. The tool uses two databases with information on the biomass properties as well as the technology criteria in order to find a match between the two. The tool gives also guidance of possible pre-treatment needed for the biomass.

In the MAGIC-project this tool was developed to include industrial crops from the MAGIC-CROPS database and their associated conversion technologies. Starting point for the development was the Bio2Match-tool developed in the S2Biom-project (FP7 project number: 608622). This version of the tool was suited only for lignocellulosic crops and their conversion technologies. In MAGIC it was expanded to include oil crops, fibre and specialty crops including their conversion technologies.

The tool is available on the internet on MAGIC-website: http://magic-h2020.eu/bio2match-tool/ It is accompanied by a user guide and a tutorial video. The biomass database and the technology database are also downloadable on the website for interested users.

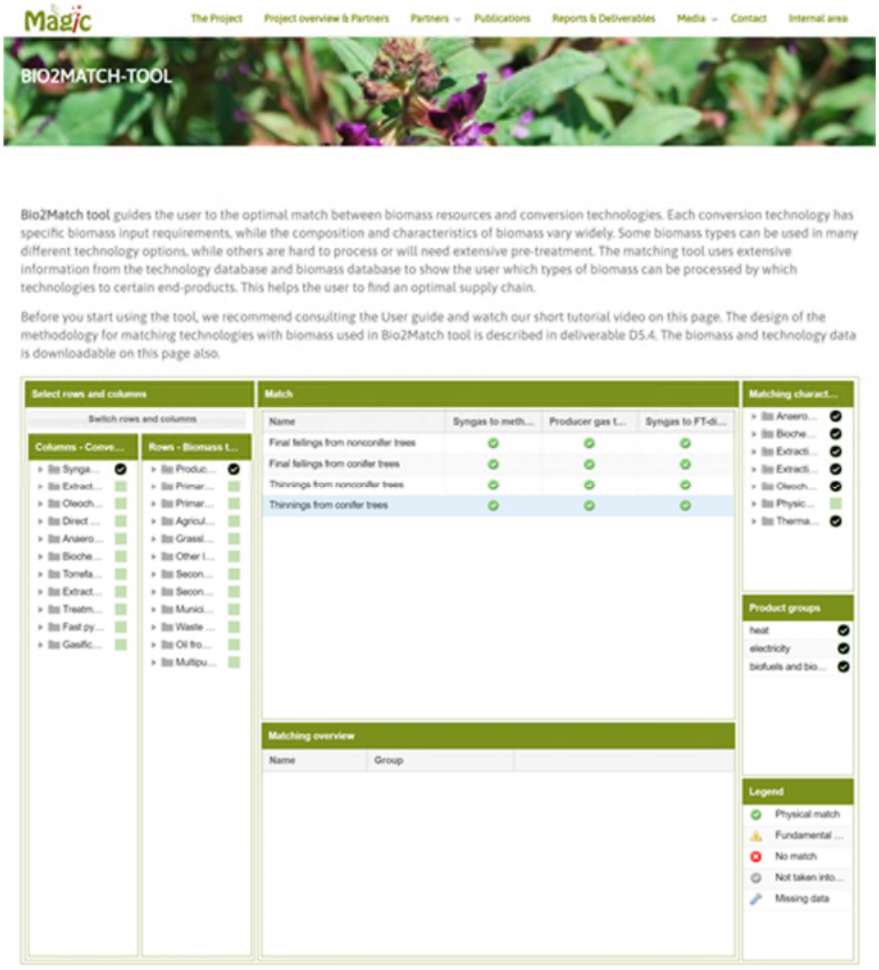


Figure 1. Bio2Match tool on MAGIC website.

2 Introduction

This document describes the development of a computerized matching tool to match industrial crops from MAGIC with their corresponding conversion technologies. The tool is made available on the internet via a user-friendly interface and is suited to serve various stakeholders, such as farmers, industrial end-users, policy makers and so on.

The starting point for this tool development was the Bio2Match-tool developed in the S2Biom-project (FP7 project number: 608622), which was developed for converting only lignocellulosic crops with associated conversion technologies. This tool was upgraded in MAGIC to include industrialised crops (MAGIC-CROPS) and their associated conversion technologies. The tool was made available on the MAGIC-website and made available for public use. The tool was accompanied by downloadable biomass and technology databases, a user guide and a tutorial video. This document explains in detail the data collection and the matching criteria created for the tool and the development of the tool.

2.1 Development process in a nutshell

Bio2Match tool offers a way to choose the most suitable conversion technology for each biomass type. The tool uses data from two extensive databases, the biomass database consisting of the biomass properties and technology database, consisting of the technology criteria. The tool was first developed in S2Biom-project to include lignocellulosic crops and their associated conversion technologies. In MAGIC it was expanded to include other industrialised crops in MAGIC-CROPS database. In Figure 2, the difference of the 2 versions is shown.

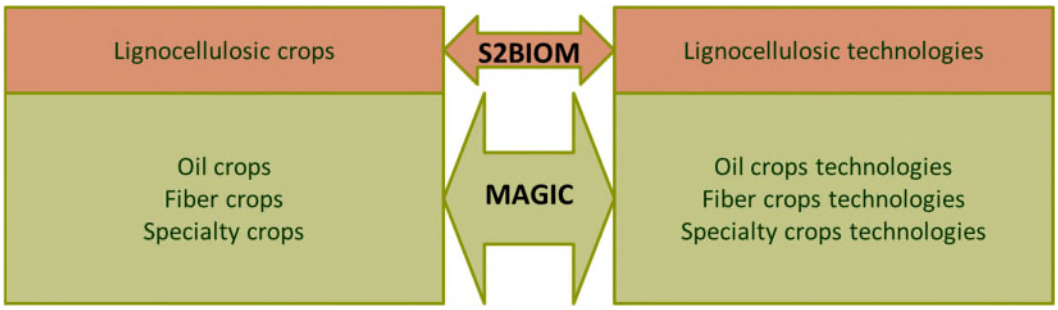


Figure 2. Illustration of the difference between

The tool development was started by gathering data from previous MAGIC tasks, namely Task 1.2 (MAGIC-CROPS database) and Task 6.2 (Selected value chains for crops from marginal lands). An overview of the tool development is illustrated in Figure 3. After gathering the necessary information for the biomass crops and the technologies a selection method was developed to create the matching between the crops and technologies. When this process was finalised, the matching criteria were included in the existing Bio2Match-tool database and the tool was upgraded.

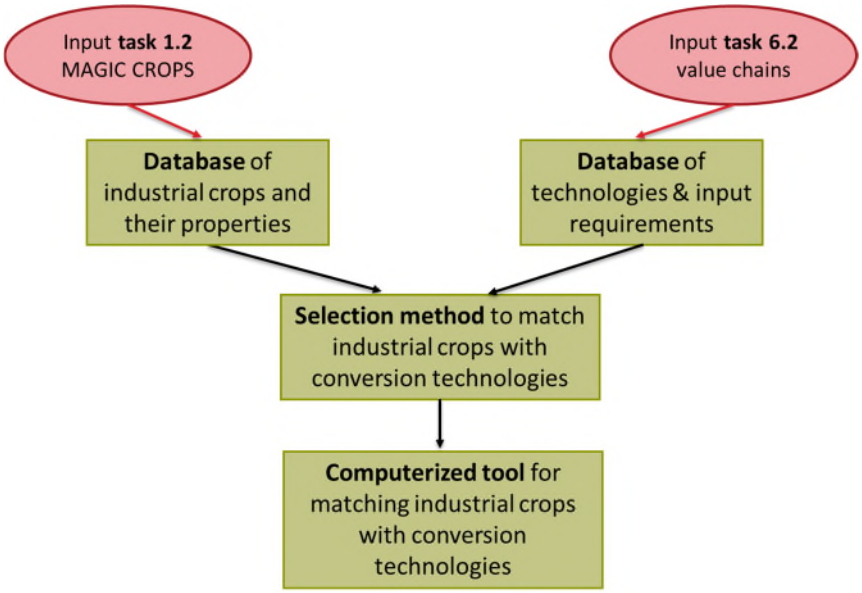


Figure 3. Overview of the steps for the tool development.

2.2 Working principle of Bio2Match-tool

The Bio2Match-tool guides the user to find a match between biomass and technologies. This is done by using a large amount of information combined from two databases. An illustration of the working principle of the tool is shown in Figure 4.

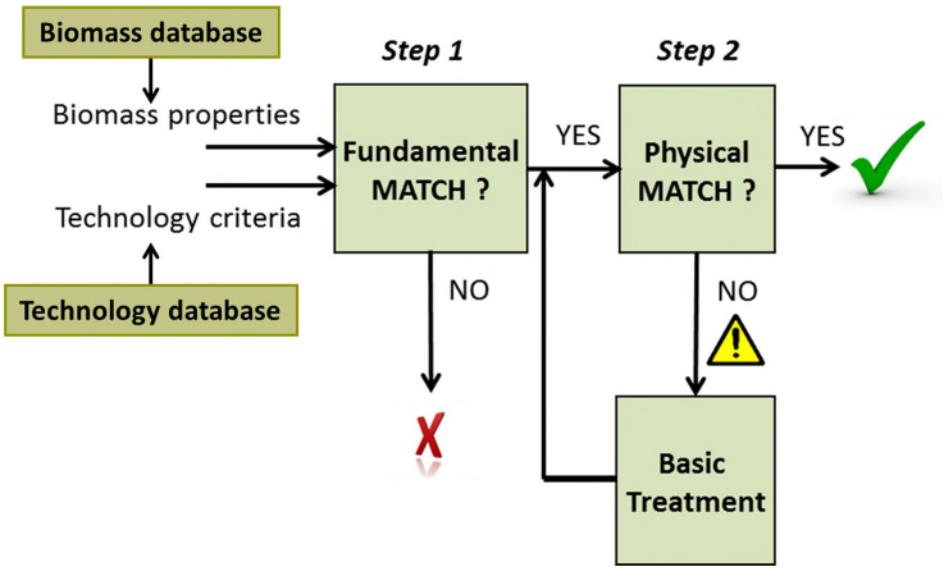


Figure 4. The working principle of the tool illustrated.

The tool checks first the biomass properties matching with the technology criteria from the corresponding databases. The first check is a fundamental match, which means checking if the biomass is suitable for the conversion process in question based on the intrinsic biomass properties. These are the properties that the biomass has after it is harvested, such as ash content, cellulose and hemicellulose content, nitrogen and chlorine content. Basically, these properties cannot be altered after the crop is harvested. If all the technology criteria are met by the biomass properties, a match is created. If any of the fundamental properties set for the conversion technology is not fulfilled, there will be no match.

After a fundamental match, it is possible to check if a physical match is possible. The physical match checks the physical properties of the biomass, such as dimensions or moisture content. Those properties can be changed after biomass is harvested by pre-treatment. If there is a match, the conversion is possible as such with the biomass that is in the tool database. If there is a no-match, the tool will indicate the physical properties that one needs to alter in order to make the conversion possible. The tool can also give an indication of the pre-treatment needed for making the conversion possible.

Bio2Match-tool can give a quick overview for the user what are the possibilities to convert various crops an certain end-products. Alternatively, one interested in a certain conversion technology can easily check the biomass that the process can handle. The following chapters will explain in more detail the process of data collection for the tool development in the MAGIC project, the matching criteria and upgrades made for the tool.

3 Biomass database

This database is providing the biomass properties for each conversion technology in the matching tool. The MAGIC-CROPS that have been added and their properties and categorization in the database in addition to the data quality are discussed in this chapter.

3.1 Biomass properties

Bio2Match tool developed in S2Biom for lignocellulosic crops was expanded to include the MAGIC-CROPS containing of oil crops, multipurpose crops, and additional lignocellulosic crops. These crops are shown in Table 1. Some of them were already included in the biomass database of Bio2Match tool and these are marked with a star (*) in the table.

To match these new crops with the conversion technologies their properties needed to be added following the requirements of the conversion technologies they are suitable for. In *(*biomass crops already included in the tool, #marginal land data)*

Table 2 the required biomass properties for each MAGIC-CROP are shown. The data for each crop was provided by the corresponding MAGIC-CROPS expert in accordance with the MAGIC-CROPS database. As the MAGIC-CROPS database is mainly focused on cultivation properties of the crops, some of the data was acquired from the literature and some was estimated. The estimations are marked in the biomass database in the corresponding cell. Furthermore, as MAGIC is focused on crops from marginal lands, it was specifically indicated if the biomass data was acquired from marginal lands conditions to be able to distinguish them from the other crops.

Table 1. MAGIC-CROPS implemented in Bio2Match-tool

Oil crops	**Lignocellulosic crops**	**Carbohydrate & Multipurpose crops**
Camelina	Switchgrass*	Lupin
Castor bean	Miscanthus*	Industrial hemp
Crambe	Giant reed*	Sorghum*
Ethiopian mustard	Tall wheatgrass[#]	
Pennycress	Reed canary grass*	
Safflower	Willow*	
	Poplar*	
	Black locust	
	Siberian elm[#]	
	Wild sugarcane / African fodder cane[#]	

*(*biomass crops already included in the tool, [#]marginal land data)*

Table 2. Required properties for each biomass category.

Biomass property	***Unit***	***Required per biomass type***		
		Sugarcrops /Multipurpose	*Oil crops*	*Lignocellulosic crops*
Moisture content	*w-% ar*	*yes*	*yes*	*yes*
Bulk density, BD	*kg/m^3 ar*	*yes*	*yes*	*yes*
Traded form	*chopped / baled / chipped, etc.*	*yes*	*yes*	*yes*
Net calorific value, dry	*MJ/kg*	*no*	*no*	*yes*
Net calorific value as received	*MJ/kg*	*no*	*no*	*yes*
Gross Calorific value	*MJ/kg*	*no*	*no*	*yes*
Ash content	*w-% dry*	*yes*	*yes*	*yes*
Ash melting behavior (DT, ox. conditions)	*°C*	*no*	*no*	*yes*
Lignin content	*w-% dry*	*no*	*no*	*yes*
Cellulose content	*w-% dry*	*no*	*no*	*yes*
Hemicellulose content	*w-% dry*	*no*	*no*	*yes*
Starch content	*w-% dry*	*yes*	*no*	*no*
Sugar content	*w-% dry*	*yes*	*no*	*no*
Nitrogen content	*w-% dry*	*yes*	*yes*	*yes*
Chlorine content	*w-% dry*	*yes*	*yes*	*yes*
Suitability for biogas production	*yes / no*	*yes*	*no*	*yes*
Biogas yield	*m^3_{biogas} /tonne DM*	*yes*	*no*	*yes*
Applicability of digestate as a solid	*yes / no*	*yes*	*yes*	*yes*
Protein content	*w-% dry*	*yes*	*no*	*no*
Fiber	*w-% dry*	*depending on the crop purpose*	*no*	*no*
Oleic acid content	*wt- % dry*	*no*	*yes*	*no*
C18:1	*wt-%*	*no*	*yes*	*no*
C18:2	*wt-%*	*no*	*yes*	*no*
C18:3	*wt-%*	*no*	*yes*	*no*
C20:1	*wt-%*	*no*	*yes*	*no*
C22:1	*wt-%*	*no*	*yes*	*no*
Triglyceride content in seed	*w-% dry*	*no*	*yes*	*no*
****Other important property of oil crops?***		*no*	*yes*	*no*
Main product	*yes/no*	*yes*	*yes*	*yes*
Residue	*yes/no*	*yes*	*yes*	*yes*
<> remarks on biomass properties		*yes*	*yes*	*yes*
Reference (data origin)		*yes*	*yes*	*yes*
Partner responsible		*yes*	*yes*	*yes*
Marginal land data	*yes/no*	*yes*	*yes*	*yes*

In the tool the biomass is categorized based on the type of biomass (*e.g.* Production from forests), followed by the subcategory (Stem wood from final fellings & thinnings) and finally by the name of the type of biomass in question (Stemwood from final fellings originating from non-conifer trees). Each biomass type has a separate entry and is separately matched with the corresponding conversion technology. This categorization is presented in detail in Annex 1.

3.1.1 Data quality

The biomass properties in the database are suited to create a match with the conversion technologies. The type of biomass data in the database represents mainly large available quantities. The biomass data from marginal lands conditions are based on the test data acquired by the MAGIC-CROPS experts. It is important to understand that biomass properties can vary largely and the data in the biomass database is combined from multiple sources.

For any crop their properties can be influenced by multiple factors, such as:

- The plant and wood species itself;
- The soil;
- The harvesting time and climate;
- The part of the plant or wood (i.e. leaf or stem) that is considered;
- The type of fertilization (if applicable).

The characteristics can also be influenced by the harvesting, collection and storage of the biomass. Furthermore, pre-treatment/drying method and (soil) contamination can affect the biomass properties. Therefore, when making assumptions or decisions based on the properties in the database it is important to keep this in mind and treat this data as indicative.

4 Conversion technologies database

This database serves in the first place as an overview of the criteria for matching biomass with the conversion technologies. Furthermore, the database also contains information about the main principle of the technology, the technology readiness level, investment costs and labour needed.

4.1 Technology additions

In MAGIC the technology database was expanded to include the conversion technologies described in the value chains selected in D6.3[1] in MAGIC. These are shown in Table 3. The technologies and crops that already existed in the tools databases are marked with a star (*). The lignocellulosic crops, such as Miscanthus, Poplar etc. have already been used in the matching tool with some of the pre-existing conversion technologies. The main additions to the tool are thermochemical fractionation of pyrolysis oil, oil conversion technologies and fibre production and extraction of protein.

Table 3. Value chains described in D6.3.

Value chain	Crop	Technology	Product
1	Miscanthus*	Pyrolysis*	Industrial heat
2	Poplar*	Gasification*	SNG
3	Switchgrass*	Fermentation*	Bioethanol
4	Willow*	Thermochemical fractionation (TCF)	Biotumen
5	Safflower	Oxidative cleavage	Acids
6	Castor	Fatty acids	Fatty acids
7	Lupin	Biorefinery/extraction	Protein
8	Hemp	Fibre production	Insulation
9	Sorghum*	Anaerobic digestion*	Methane

The technologies are categorized into groups following the type of conversion technology. This categorization is shown in Table 9 in Annex 1. All the new additions are shown in bold text.

4.1.1 Technology criteria and the matching criteria

For each technology conversion criteria were collected according to the task division in D6.3. Several criteria were provided for each technology. Based on these criteria and the biomass properties, the matching criteria were defined. The matching criteria for the technologies described in value chains (VC) 5 and 6 are shown in Table 4, which shows the fundamental and physical criteria for the required match.

Fundamental characteristics are classified from 1 to 4, with 1 being the most desirable property value and 4 being not allowed. The first criterion is that the crop is an oil crop (yes/no). Then the oil composition and oil properties are listed. Properties marked with (P) are physical properties that cause over consumption of oxidant in the process. This increases prices, and therefore, the purification of these oil components prior the process is desired.

For these two value chains only one MAGIC-CROP was possible to match with each technology, these are Castor and High Oleic Acid Safflower. As the seed processing to the oil is not part of the described technologies and the biomass properties only contained the oil properties, it was decided to match the Alkali pyrolysis for fatty acids production with Oil from Castor and the Oxidative cleavage for acids production with Oil from High Oleic Acid Safflower.

Table 4. Matching criteria for the oleochemical processes described in value chains 5 and 6. These are all fundamental criteria except for the ones marked in (P). This means this criterion is set as physical criterial.

Oleochemical processes					
Alkali pyrolysis for fatty acids production (Sebasic acid DC 10 and 2-Octanol)					
Fundamental characteristics		most desirable	desirable	undesirable	very undesirable
		1	2	3	4
Oil crop?	(Castor oil)	yes			no
Oil content needed	wt%	40	30	20	<20
Oil composition needed					
C18:1, OH		80	50	45	<45
Oxidative cleavage for acids production (Azelaic acid DC9 and Pelargonic acid C9)					
Fundamental characteristics		most desirable	desirable	undesirable	very undesirable
		1	2	3	4
Oil crop	(High oleic acid safflower oil)	yes			no
Oil content needed	wt%	40	30	20	<20
Oil composition needed					
C18:1	wt%	75	60	50	<50
C18:2(P)	over consumption of oxydant	5	10	15	>15
C18:3(P)	over consumption of oxydant	5	10	15	>15

As these were the only oil conversion technologies described in D6.3[1] and they are suited only for one crop each, it was decided to consider also other oil conversion technologies to expand them. Several technologies were described earlier in D6.2[2] and these technologies were added to the technology database with the criteria described in Table 5. As can be seen the matching criteria for these technologies are based on three characteristics: oil crop, oil content and the associated oil properties of the oil. E.g. for Transesterification for FAME production, C22:1, and C18:1 are necessary properties from these crops, which Oil from Ethiopian Mustard seed and Oil from High Oleic Acid Safflower fulfil.

Table 5. Other oleochemical processes added to the matching tool and their matching criteria.

Oleochemical processes **Fundamental characteristics**		**most desirable**	**desirable**	**undesirable**	**very undesirable**
		1	2	3	4
Oil crop?		yes			no
Oil content		25	20	15	<15
Transesterification for FAME production	Oil from Ethiopian Mustard seed, Oil from High Oleic acid Safflower	C22:1, C18:1			others
Esterification for fatty esters production	Oil from Crambe, Oil from High Oleic acid Safflower	C18:1, C18:3, C22:1			others
Amidation for fatty amines production	Oil from Crambe, Oil from High Oleic acid Safflower	C18:1, C18:3, C22:1			others
Nitrile route to fatty aminesproduction	Oil from Crambe, Oil from High Oleic acid Safflower	C18:1, C18:3, C22:1			others

Oleochemical processes Fundamental characteristics		most desirable	desirable	undesirable	very undesirable
Hydrogenation for fatty alcohols production	Oil from Crambe, Oil from High Oleic acid Safflower	C18:1, C18:3, C22:1			others
Intermolecular condensation for oligormers production	Oil from Castor bean, Oil from High Oleic acid Safflower	C18:1, C18:1, OH			others
Heat polymerisation for blown/stand oil production	Oil from Crambe, Oil from Camelina, Oil from Castor, Oil from High Oleic acid Safflower	C22:1, C20:1, C18:1, OH, C18:1			others
Polycondensation for alkyd resins production	Oil from Crambe, Oil from Camelina, Oil from Castor, Oil from High Oleic acid Safflower	C22:1, C20:1, C18:1, OH, C18:1			others
Polyamidation for polyamide production	Oil from Castor bean	C18:1,OH			others
Hydrolysis for short chain fatty acids production	Oil from Castor bean, Oil from High Oleic acid Safflower	C18:1, C18:1, OH			others

Oleochemical processes Fundamental characteristics		most desirable	desirable	undesirable	very undesirable
Epoxidation for epoxidized oil production	Oil from Castor bean, Oil from High Oleic acid Safflower	C18:1, C18:1, OH			others
Olefin metathesis for chemical building blocks production	Oil from High Oleic acid Safflower	C18:1			others
Oxidative cleavage for carboxylic acids production	Oil from Crambe, Oil from High Oleic acid Safflower	C18:1, C18:3, C22:3			others

For value chains 7 and 8 (Table 3) multipurpose crops were utilized. The matching criteria for Extraction of protein are shown in Table 6. For this technology, the most important characteristic is the protein content of the Lupin seed.

Table 6. Matching characteristics for Extraction of protein.

Extraction of protein Fundamental characteristics		most desirable	desirable	undesirable	very undesirable
		1	2	3	4
Extraction of micellar lupin protein					
Crop for protein extraction (Lupine)	Yes or no	yes			no
Minimum extractable protein content (of the dehulled seed)		>41%	35%	31%	<31%

For processing of Industrial Hemp for fibre containing products, the matching criteria are shown in Table 7. The value chain example is marked with (VC). As for the Oleochemical processes, also for processing hemp other conversion options were sought out as the VC example only provided one option. The complimentary conversion options are listed in Table 7 after the VC example.

Table 7. Characteristics for matching Industrial Hemp with fibre processing technologies. The value chain example in D6.3 is marked with (VC). Physical property is marked with (P).

Extraction of fibers					
Fundamental characteristics		**most desirable**	**desirable**	**undesirable**	**very undesirable**
		1	2	3	4
Fiber processing of hemp to insulation material (VC)					
Fiber crop?	Yes or no	yes			no
Amount of fibers	wt%	>25%	20	15	<15
Moisture content(P)	% as received	<20	20	35	>50%
Hemp fiber processing for composite material					
Fiber crop?	Yes or no	yes			no
Amount of fibers	wt%	>25%	20	15	<15
Hemp fiber processing for agro textile					
Fiber crop?	Yes or no	yes			no
Amount of fibers	wt%	>25%	20	15	<15
Hemp fiber processing for pulp and paper					
Fiber crop?	Yes or no	yes			no
Amount of fibers	wt%	>25%	20	15	<15

For value chain example 4 using Thermochemical Fractionation of pyrolysis oil, the same criteria as for Fast Pyrolysis of Clean wood was used. These criteria among the criteria for other Thermal Conversion technologies, Biochemical conversion and Anaerobic digestion were defined in the S2Biom-project and they can be found in S2Biom Deliverable 2.2 (A selection method to match biomass types with conversion technologies).

4.1.2 Matching tool

Following the determination of the matching criteria, the information was implemented in the online database and the tool was adjusted to include the new technologies. Furthermore, the appearance of the tool was designed to reflect the project's colour scheme. An overview is presented in Figure 5. For the tool, a webpage on the MAGIC-website was created by partner Nova. Bio2Match-tool is linked to this website and presented there.

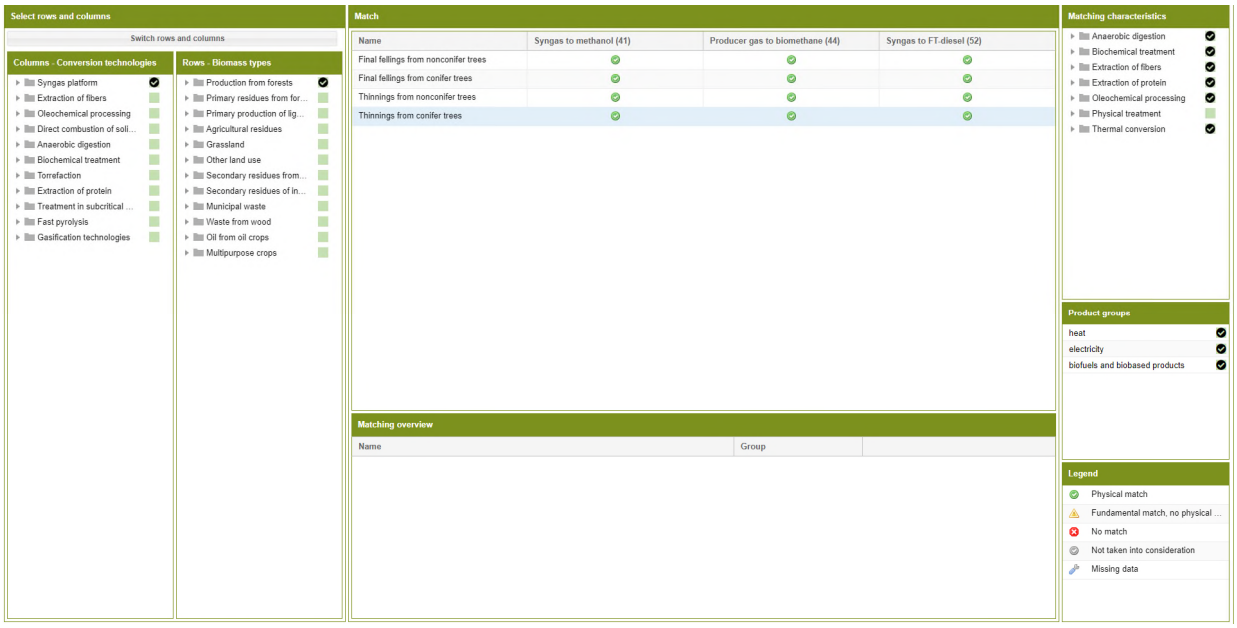


Figure 5. Overview of Bio2Match-tool's appearance.

4.1.3 Additional information for conversion technologies

Additional information about the conversion technologies presented in the value chain examples was also gathered to compliment the users of the tool with more information. The information is combined in the technology database that is made available for the user to download on the project website.

The list of additional information gathered for each technology is:

- Main operating principle
- Level of commercial application
- Important pilots and EU projects
- Expected Developments
- Year of first implementation
- Estimated number of systems in operation
- Current Technology Readiness Level in 2020
- References
- Data sources used to define conversion efficiencies
- Indication: experience-based data
- Number of possible full load hours per year (hours)
- Number of typical full load hours per year (hours)
- Typical Lifetime of Equipment (years)
- General data sources for technical properties
- Biomass input, common for the technology used

- Biomass input, technically possible but not common
- Traded form
- Required biomass properties
- Investment costs 2020 (€)
- Operators (FTE)
- Staff and engineering (FTE)
- Technology Inputs (additional to biomass)
- Technology Outputs
- Conversion Efficiencies

In addition, the existing information in this database from S2Biom was reviewed and experts knowledgeable of these technologies were consulted to bring the data up to date. The revised data is included with the technology database.

4.1.4 User guide and material

Ensuring user-friendliness, a user guide was created to help the users to get acquainted with the tool. The user guide is added in Annex 2 of this document. Furthermore, a short video tutorial was also created showing the user how to use the tool. The tutorial video was linked on the website of the tool as well to ensure quick and ease of access.

In addition to the user guide, the biomass database and the technology database are both downloadable on the webpage of the tool.

5 Conclusion

The matching tool for matching industrial crops with their associated conversion technologies was developed and made available on the internet through a user-friendly interface and guidance media.

The tool development started with gathering data from Task1.2 for the biomass properties and Task 6.2 for the conversion technologies. This data was then expanded to include information for matching the crops with the various technologies. Furthermore, the selection of conversion technologies was expanded for oil conversion technologies and fibre processing technologies to offer more conversion options for the MAGIC-CROPS. In addition to this, the technology database from S2Biom containing additional information about the technologies was updated. This information was adapted by the tool's databases. The tool was then modified to include the new technologies and biomass types and the visual appearance was designed to reflect MAGIC's visual identity.

The tool is available on the MAGIC-website: http://magic-h2020.eu/bio2match-tool/. The biomass database and technology database are downloadable on the website. To ensure user-friendliness a user guide was created, and a tutorial video was made to help interested users to get acquainted with the tool. The task is now completed.

The progress of the task and the completed tool were presented in MAGIC General Assembly on June 30th 2021.

6 References

1. *D6.3 – Report on Technologies and Market Volumes of the Selected Value Chains*.; 2018.
2. *D6.2 – Technology and Market-Based Selection of Value Chains for the Sustainability Assessment*.; 2020.

7 Annex 1

Table 8. Biomass categorization in the tool. Categories, subcategories and types marked in bold are MAGIC-CROPS.

Category name	Subcategory name	Type name
Production from forests	Stemwood from final fellings & thinnings	Stemwood from final fellings originating from nonconifer trees
		Stemwood from final fellings originating from conifer trees
		Stemwood from thinnings originating from nonconifer trees
		Stemwood from thinnings originating from conifer trees
Primary residues from forests	Logging residues from final fellings & thinnings	Logging residues from final fellings originating from nonconifer trees
		Logging residues from final fellings originating from conifer trees
		Logging residues from thinnings from nonconifer trees
		Logging residues from thinnings from conifer trees
	Stumps from final fellings & and thinnings	Stumps from final fellings originating from nonconifer trees
		Stumps from final fellings originating from conifer trees
Primary production of lignocellulosic biomass crops	Energy grasses, annual & perennial crops	Miscanthus (Perennial grass)
		Switchgrass (Perennial grass)
		Giant reed (Perennial grass)
		Cardoon (Perennial crop)
		Reed Canary Grass (Perennial grass)
		Tall Wheatgrass from marginal lands
		African fodder cane from marginal lands
		Sorghum
	Short rotation coppice	SRC Willow
		SRC Poplar
		Other SRC
		SRC Black Locust
		SRC Siberian Elm from marginal lands
Agricultural residues	Straw/stubbles	Rice straw
		Cereals straw
		Oil seed rape straw
		Maize stover
		Sugarbeet leaves
		Sunflower straw
	Woody prunning & orchards residues	Residues from vineyards
		Residues from fruit tree plantations (apples, pears and soft fruit)
		Residues from olives tree plantations

Category name	Subcategory name	Type name
		Residues from citrus tree plantations
		Residues from nuts plantations
Grassland	Grassland	Unused grassland cuttings (abandoned grassland, managed grasslands not used for feed)
Other land use	Biomass from road side verges	Grassy biomass from road side verges
Secondary residues from wood industries	Saw mill residues	Sawdust from sawmills from conifers
		Sawdust from sawmills from nonconifers
		Sawmill residues: excluding sawdust, conifers
		Sawmill residues: excluding sawdust, nonconifers
	Other wood processing industry residues	Residues industries producing semi finished wood based panels
		Residues from further woodprocessing
	Secondary residues from pulp and paper industry	Bark residues from pulp and paper industry
		Black liquor
Secondary residues of industry utilising agricultural products	By-products and residues from food and fruit processing industry	Olive-stones
		Other by-products and residues from food and fruit processing industry
		Rice husk
		Pressed grapes dregs
		Cereal bran
Municipal waste	Biodegradable municipal waste	Biowaste as part of integrally collected municipal waste: Biodegradable waste of not separately collected municipal waste (excluding textile and paper)
		Separately collected biowaste: Biodegradable waste of separately collected municipal waste (excluding textile and paper)
Waste from wood	Post consumer wood	Hazardous post consumer wood
		Non hazardous post consumer wood
Oil from oil crops	**Oil from oil crops**	**Oil from Camelina**
		Oil from Castor bean
		Oil from Crambe
		Oil from Ethiopian Mustard seed
		Oil from High oleic acid Safflower
Multipurpose crops	**Multipurpose crops**	**Lupin seed**
		Industrial hemp

Table 9. Categorization of the conversion technologies.

Category	Subcategory	Process name
Thermal conversion technologies		
Direct combustion of solid biomass	Fluidised bed combustion for CHP (steam cycle)	BFB direct combustion
		CFB direct combustion
	Fixed bed combustion for heat	Grate boiler for heat
	Fixed bed combustion for CHP (steam cycle)	Grate boiler with wood chips for CHP
		Grate boiler with agrobiomass for CHP
	Direct co-combustion in coal fired power plants	Co-firing in PC
	Waste incinerators with energy recovery	Grate fired waste incinerator
	Domestic pellet burners for heat	Pellet boiler for heat
	Domestic residential batch fired stoves for heat	Batch stove for heat
Gasification technologies	Circulating Fluidized bed for CHP (gas engine)	CFB for CHP
	Circulating Fluidized bed for IGCC	CFB for IGCC
	Bubbling fluidized bed for CHP (gas engine)	BFB for CHP
	Circulating Fluidized bed for syngas production	CFB for syngas
	Dual Fluidized bed for CHP (gas engine)	DFB for CHP
	Dual Fluidized bed for syngas production	DFB for syngas
	Entrained flow for syngas production	Entrained flow for syngas
	Fixed bed (downdraft) for CHP (gas engine)	Fixed bed for CHP
	Fixed bed (updraft), direct combustion	Fixed bed, direct combustion
	Bubbling fluidized bed for IGCC	BFB for IGCC
	Bubbling fluidized bed for syngas production	BFB for syngas
Syngas platform	Fluidised bed gasification for methanol production	Syngas to methanol
	Indirect gasification for SNG production	Producer gas to biomethane
	Fluidised bed gasification for FT-fuels production	Syngas to FT-diesel
Fast pyrolysis	Pyrolysis plus boiler for heat and steam	Fresh wood chips to pyrolysis oil
		Agricultural residues to pyrolysis oil
		Pyrolysis oil to heat
		Pyrolysis oil to steam

Category	Subcategory	Process name
	Pyrolysis and hydrogenation for diesel fuel	Pyrolysis oil diesel
	Pyrolysis oil and diesel engine for electricity	Pyrolysis combustion engine (compression-ignition)
		CHP Gas Turbine
	Pyrolysis plus boiler for heat and steam	Pyrolysis plus boiler for heat, integrated
	Pyrolysis plus boiler for heat and steam	Pyrolysis plus boiler for steam, integrated
	Pyrolysis oil and diesel engine for electricity	Pyrolysis plus combustion engine, integrated
	Pyrolysis oil and diesel engine for electricity	Pyrolysis plus CHP, integrated
	Pyrolysis oil and FCC Co-processing	**Co-processing of FPBO in FCC**
	Pyrolysis oil thermochemical fractionation	**Fast pyrolysis oil thermochemical fractionation to pyrolytic sugars, VC example**
		Fast pyrolysis oil thermochemical fractionation to pyrolytic lignin, VC example
Torrefaction	Moving bed reactor	Torrefaction and pelletisation (TOP)
(Bio-)chemical conversion technologies		
Techniques from pulp and paper industry	Kraft process with LignoBoost process	Kraft process with Lignoboost
	Prehydrolysis Kraft process in water phase	Prehydrolysis kraft
Chemical pretreatment	Alkaline hydrolysis	Alkaline hydrolysis
	Dilute acid hydrolysis	Dilute acid hydrolysis
Biochemical hydrolysis and fermentation	Enzymatic hydrolysis	Enzymatic hydrolysis alkaline pretreated
		Enzymatic hydrolysis acid pretreated
	Fermentation	Fermentation alkaline pretreated
		Fermentation acid pretreated
Biochemical ethanol and biobased products	Simultaneous saccharification and fermentation	Ethanol from lignocellulose (dilute acid pretreatment), value chain example
Treatment in subcritical water	Aqueous Phase Reforming	Aqueous Phase Reforming
	Hydrothermal processing	HTC Hydrothermal carbonisation of biowaste to coal for CHP
Anaerobic digestion technologies		
Anaerobic digestion	Complete mix digester	Complete mix digester state of the art 2014
Anaerobic digestion	Plug flow digester	Dry Batch Digestion (MSW)
(Oleo-)chemical conversion technologies		
Oleochemical processing	**Alkali pyrolysis**	**Alkali pyrolysis for fatty acids production (Sebacic Acid DC10, 2- Octanol), VC example**
	Oxidative cleavage	**Oxidative cleavage for Azelaic acid (DC9) and Pelargonic acid (C9) production, VC example**
	Transesterification	**Transesterification for FAME production**
	Esterification	**Esterification for fatty esters production**
	Amidation	**Amidation for fatty amines production**

Category	Subcategory	Process name
	Amines via nitrile route	Nitrile route to fatty aminesproduction
	Hydrogenation	Hydrogenation for fatty alcohols production
	Intermolecular condensation	Intermolecular condensation for oligormers production
	Heat polymerisation	Heat polymerisation for blown/stand oil production
	Polycondensation	Polycondensation for alkyd resins production
	Polyamidation	Polyamidation for polyamide production
	Hydrolysis	Hydrolysis for short chain fatty acids production
	Epoxidation	Epoxidation for epoxidized oil production
	Olefin metathesis	Olefin metathesis for chemical building blocks production
	Oxidative cleavage	Oxidative cleavage for carboxylic acids production
Mechanical processing technologies		
Extraction of protein	Salt induced protein extraction	Extraction of micellar lupin protein, VC example
Fiber processing	Hemp fiber processing for insulation material	Hemp fiber processing for insulation material, VC example
	Hemp fiber processing for composite material	Hemp fiber processing for composite material
	Hemp fiber processing for agro textile	Hemp fiber processing for agro textile
	Hemp fiber processing for pulp and paper	Hemp fiber processing for pulp and paper

8 Annex 2

Bio2Match-tool

User guide

Horizon 2020
European Union Funding
for Research & Innovation

Magic
Marginal lands for Growing Industrial Crops

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 727698.

Bio2Match tool

Bio2Match tool guides the user to the optimal match between biomass resources and conversion technologies. The conversion technologies have specific requirements for the biomass input while biomass varies widely in composition and characteristics.

The tool uses **2 databases** to find **an optimal match** for each biomass and technology.

One database consist of **technology criteria**, specific for each technology. The other database consist of **biomass characteristics**. The matching tool uses these databases to create an optimal match for each technology and biomass. This helps the user to find the most suitable combination to process biomass to certain end-products.

In the next slides one can see step by step how to select the conversion technologies and biomass, the matching overview and the details of the matches and no-matches.

Bio2Match tool is developed by BTG Biomass Technology Group and Wageningen University and Research. The tool is first released in S2Biom-project and upgraded further in MAGIC-project.

The tool is available at: http://magic-h2020.eu/bio2match-tool/

btg biomass technology group

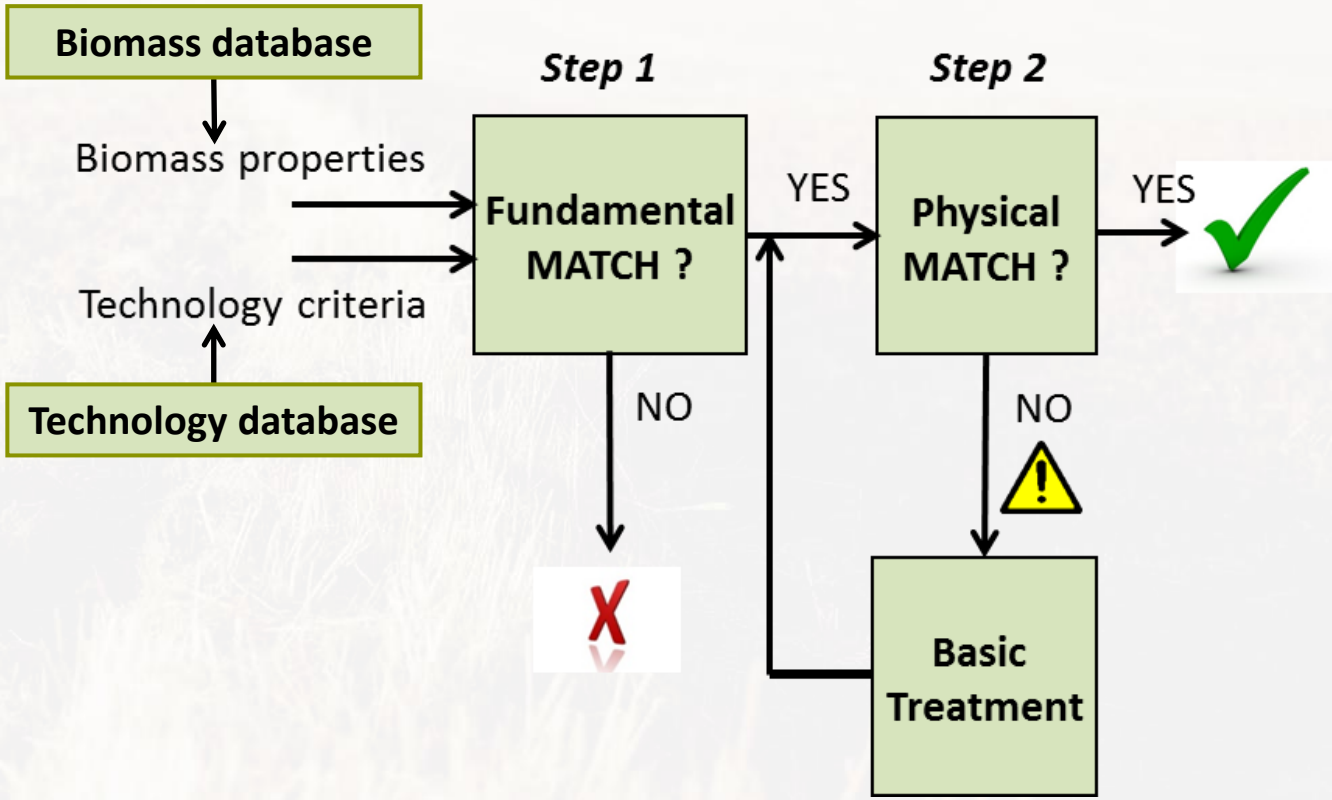
Magic

WAGENINGEN UNIVERSITY & RESEARCH

Table of contents

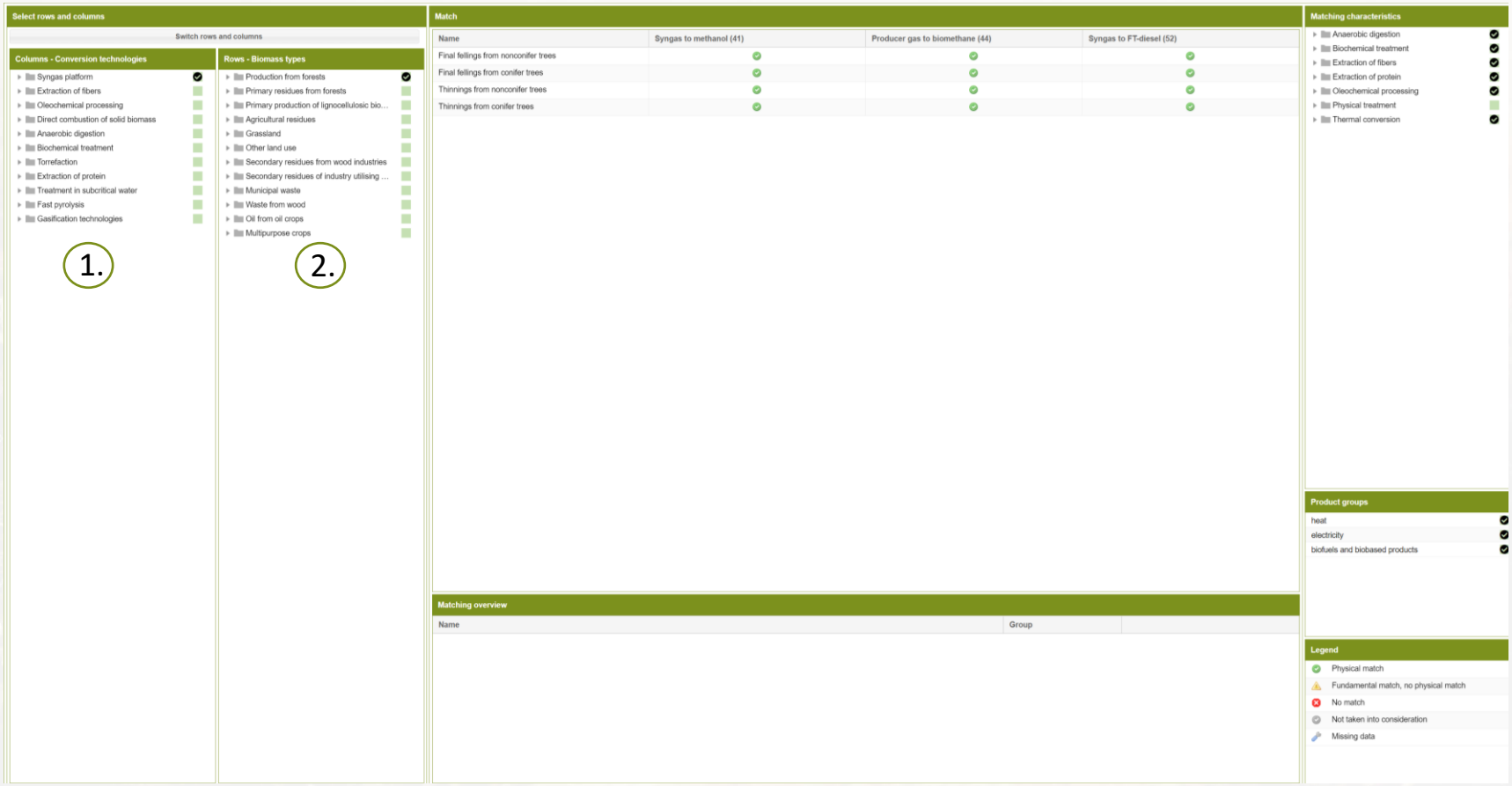
Working principle of the tool

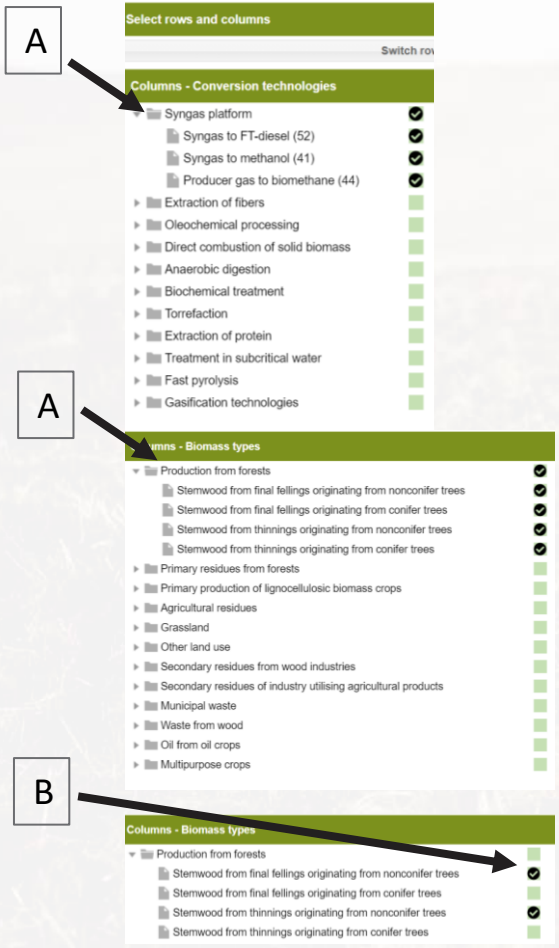
- The tool will use biomass properties and the technology criteria to make a match.
- If there is a fundamental match, the conversion can be carried out.
- In case there is no physical match a pre-treatment, such as drying, can be carried out to make the conversion possible.
- The tool allows to search and review several biomass types and conversion technologies at one glance.



Getting started

Below is the tool window as user will see it when starting. On the most left are **Conversion technology** categories in the tool (1). Next to it are **Biomass types** (2).





Making the selection

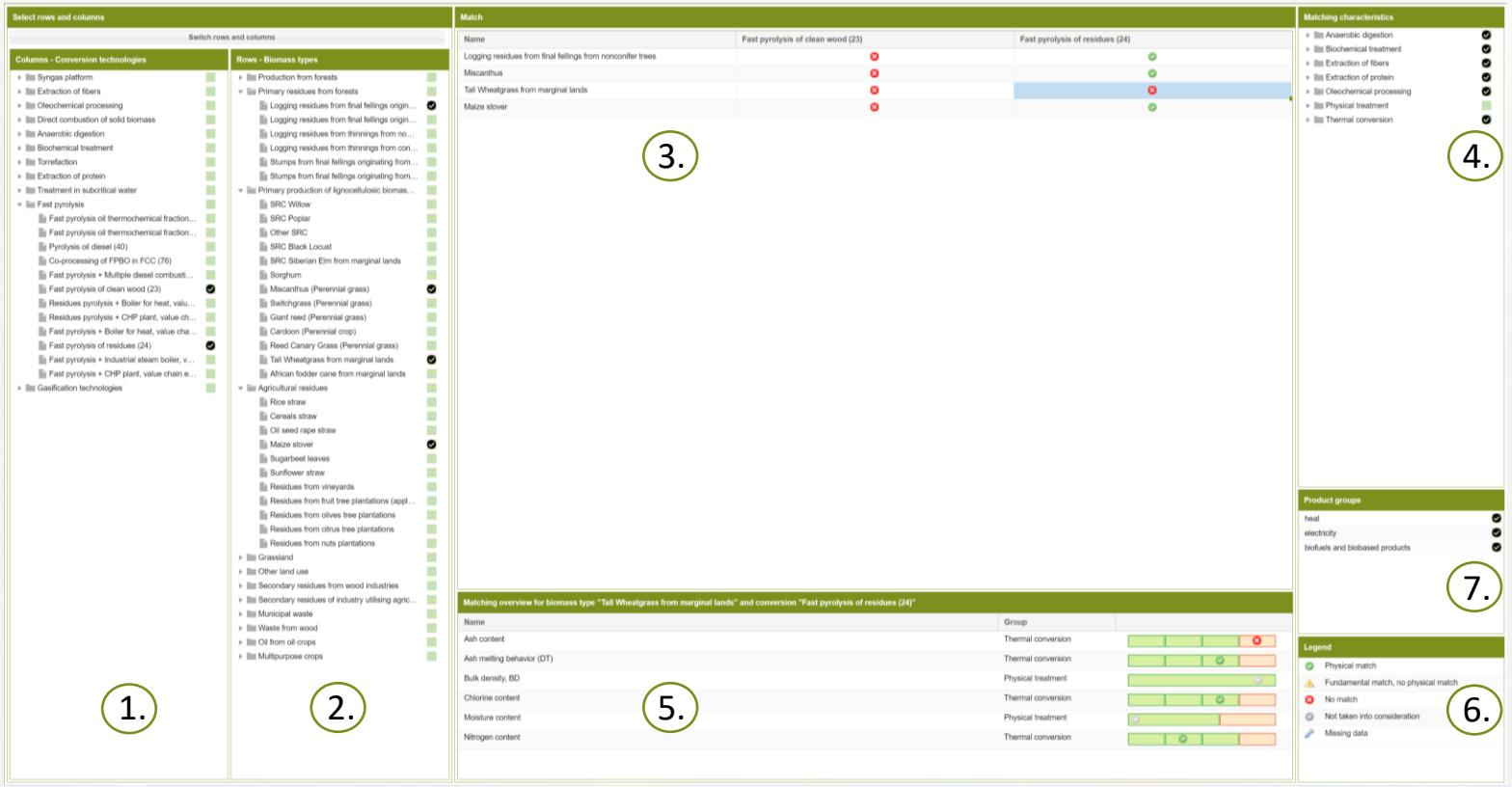
A) By clicking each group, one can see all the possible conversion technologies/biomass types under the category.

For example: under Syngas platform one can see three different conversion options. Under Production from forests, all this type of biomass in the database is shown.

B) One can select the whole group, like in the top two figures, or select only some of them for the comparison.

Looking at the Match overview

When one has selected the conversion technology and the biomass types of interest, the match is shown in the middle in the **Match** box (3). The green mark indicates **a match** and the red cross indicates **a no-match**.
The characteristics that are taken into account for the matching are shown in box (4). By default all of them, except *Physical treatment* is selected. This is explained in more detail in the next slide.
When one selects one of the **match**/**no-match** (box 3), **Matching overview** (5) shows an explanation.
The symbols used in the tool are shown in the **Legend** box (6). One can filter out their desired product in the **Product groups** box (7). This selection removes the conversion technologies from the selection that do not produce this product.



Details of the Match 1/2

The matching is taking into account the fundamental and physical properties of the biomass. Fundamental properties are properties that cannot be affected after harvesting these are, for example, ash content, ash melting behaviour, chlorine and nitrogen content. Physical properties are the density and moisture content, which can be influenced by a pre-treatment of the biomass. For example, to make too moist biomass suitable to be processed by drying.

In **Matching characteristics** (4), *Physical properties* is by default un-selected. This way the user always has the fundamental match shown. First the match/no-match concept is explained with this setting.

Match

Matching overview (5) shows all the criteria taken into account for the match. In the selected case the following fundamental properties constitute to the match:

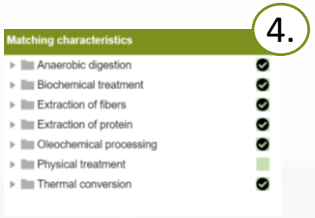
- Ash content
- Ash Melting behaviour (DT)
- Chlorine content
- Nitrogen content

The green marker appears in top of the green box (see black circle) for indication that the biomass properties are matching with the technology criteria in a specific range or class. These are explained in more detail on page 10.

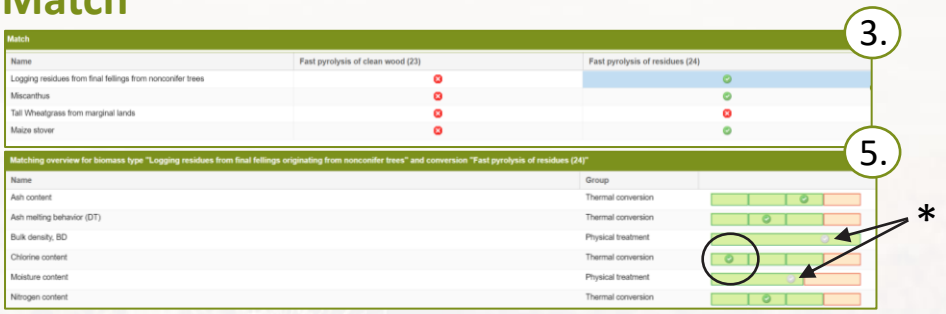
As *Physical properties* (*) *are* not selected in **Matching characteristics** (4), these are not taken into account and the marker is grey, as described in the **Legend**.

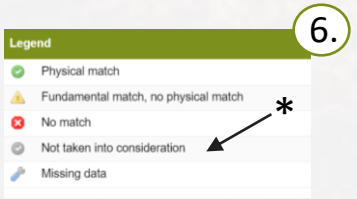
No-match

In this case, same properties are taken into account as for above. **Matching overview** (5) shows that the reason for excluding the biomass (*Tall wheatgrass from marginal lands*) is because the *Ash content* is too high. *Ash content* is a fundamental property and therefore it results in a no-match.

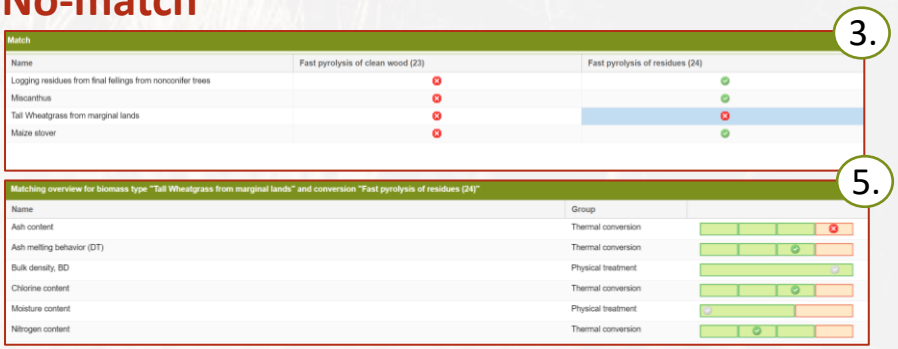


Match





No-match

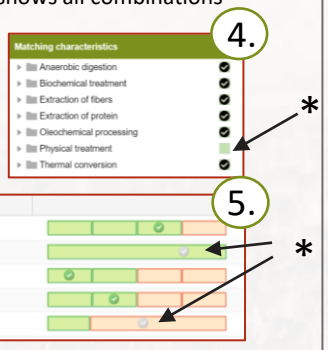


Details of the Match 2/2

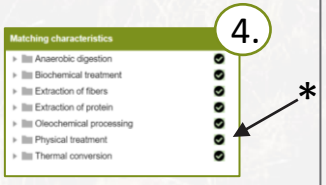
Here the difference between fundamental match and physical match is explained.

For this example, another technology (*Ethanol from lignocellulose*) is chosen in the **Conversion technology** (1), the biomass selection remains the same. As by default the *Physical properties* (*) in the **Matching characteristics** (4) is not selected. And the **Match** box (3) shows all combinations matching.

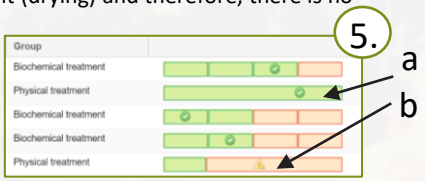
Matching overview (5) shows also that *Physical treatment* is grey (not taken into account).

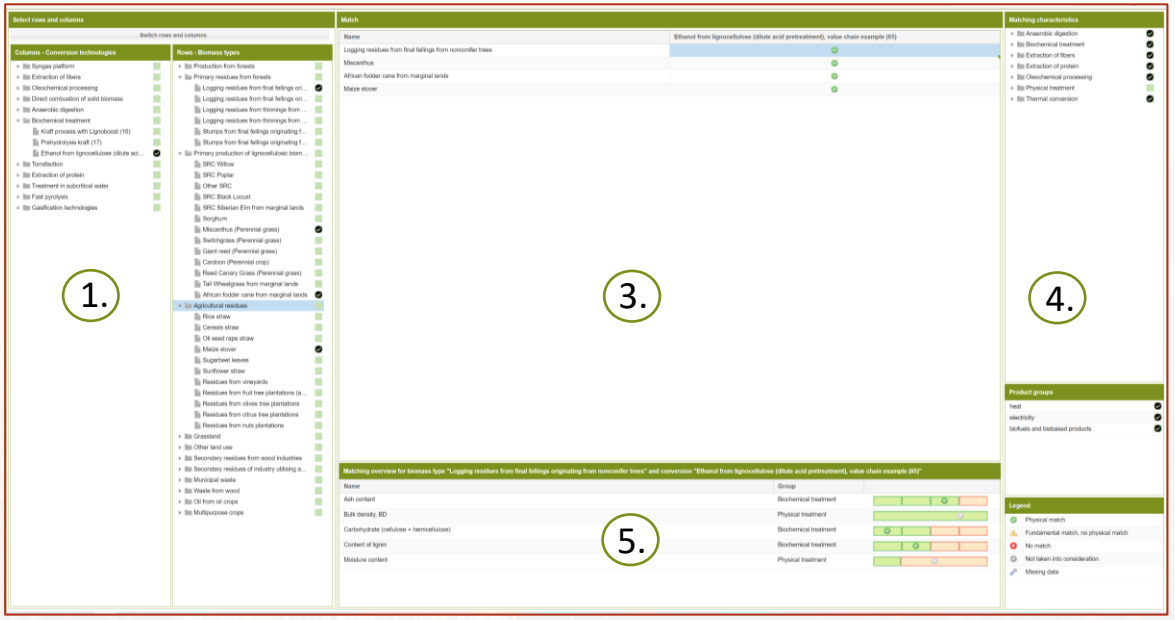


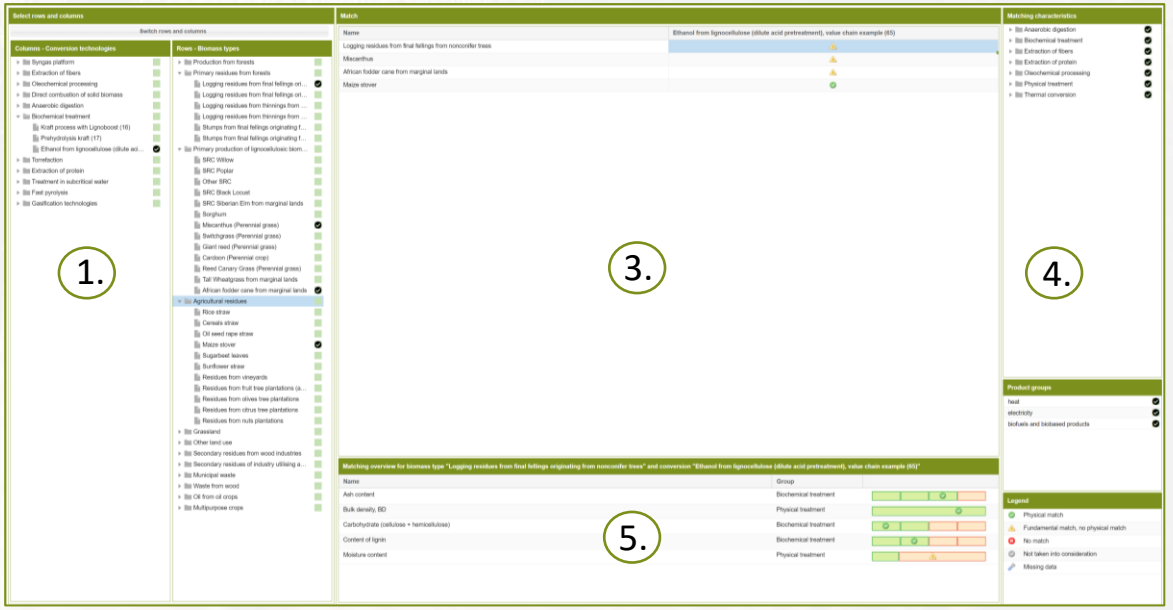
When selecting the *Physical properties* (*) in the **Matching characteristics** (4) one can see that the overview changes (see the figure on the right).



A triangle appears where a match was indicated in the **Match** box (3). ⚠ This indicates that fundamental match is possible, but physical match is not. The **Matching overview** (5) has changed now also. A grey marker for *Bulk density* has turned green (arrow a). For *Moisture content* the triangle has appeared (arrow b) meaning that it is too high and the biomass needs a pre-treatment (drying) and therefore, there is no physical match.







More information about the matching criteria and the matches

It is possible to get more insights from the tool on the matching criteria and biomass suitability for each conversion technology. This can be found in the **Matching overview** (5) box. By clicking the arrow pointed at (a), one can open a dropdown menu. By clicking *Columns*, one can select more information for the **Matching overview** (5) box.

In this example (**Matching overview** (5A)), the following are shown:

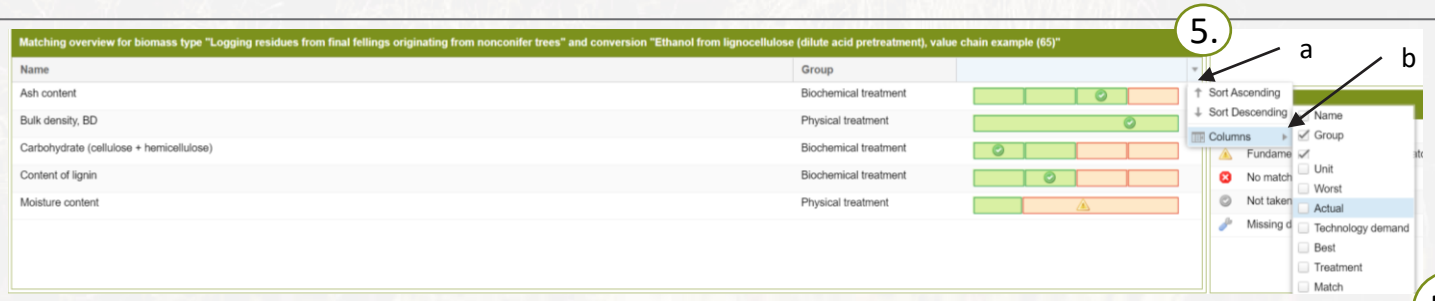
- *Unit*
  - Shows the units used for the data. If the data is classified, the ranges for each class are described. For example, *Ash content* is classified as follows: Class 1: ≥1w-% dry, Class 2: 1-3 1w-% dry, Class 3: 3-10 w-% dry, Class 4: >10 w-% dry.

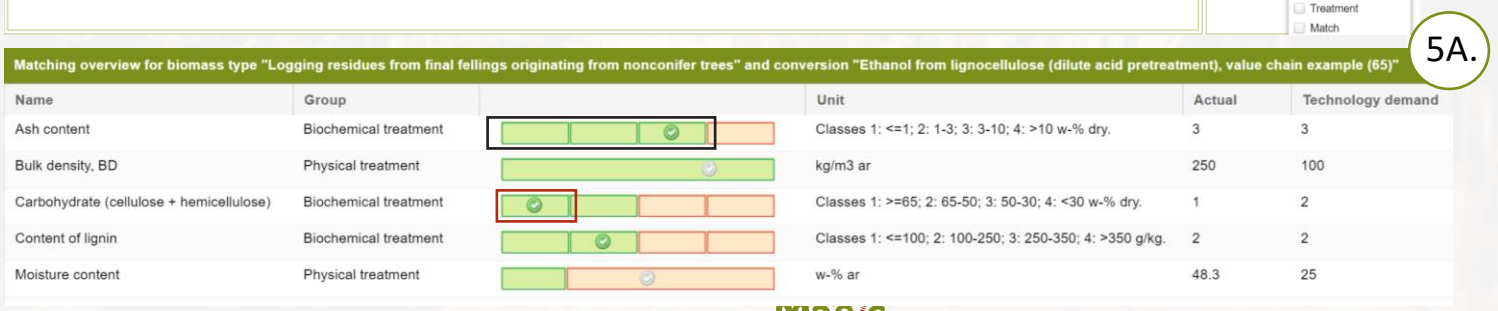
- *Actual*
  - Shows the actual property for the biomass. For example, *Bulk density, DB* is 250 kg/m^3 as received. If the criteria is classified, it shows the class the biomass belongs to. This is also indicated by the position of the green marker over the boxes. Please see the red box in *Carbohydrate (cellulose + hemicellulose)* group.

- *Technology demand*
  - Shows the requirement for the technology. For example, for *Bulk density, DB* this is 100 kg/m^3 as received. The number of green boxes shows the classes that the technology allows. Please see the black box over *Ash content* group.

The meaning of the other options (not shown) in the drop down menu are:

- *Best, Worst*
  - The best and worst-case values of the biomass properties.
- *Treatment*
  - The pre-treatment needed when physical match is not possible.
- *Match*
  - Shows the match or no-match for each characteristic.





Final remarks

- The tool is available on the MAGIC website: http://magic-h2020.eu/bio2match-tool/
- On this webpage a short tutorial for the tool is available.
- The biomass database and the technology database are downloadable on this webpage.
- Background photo by Siebe Warmoeskerken on Unsplash.