# Introduction

Potatoes are starchy crops that represent the world’s fourth most important crop. Valorization of potato wastes and particularly peels, would be an advantageous approach for transforming waste into valuable products, including chemicals, energy sources, food ingredients. Such valorizations aim to reduce waste, enhance sustainability, and create economic value from what would otherwise be an obstacle to the sustainability.

# Define the general data system

Table 1 includes the initial information that must be defined in the software regarding plant production, capital cost calculations, and possible heat recovery systems.

Table 1. Definition of general system parameters

|  |  |  |
| --- | --- | --- |
|  | **Parameter** | **Value** |
| **Specific production** | Load type | Substrate |
| Main product / Substrate | Potato peel |
| Substrate load (t/y) | 560 000 |
| **General CAPEX**  **parameters** | Operating hours (h/y) | 8000 |
| Year of Study | 2020 |
| Interest rate (-) | 0.05 |
| Detail level of linearization of CAPEX | Real |
| Indirect Cost Factor (-) | 1.44 |
| Direct Cost Factor (-) | 2.60 |
| **Heat pump parameters** | Heat pump switch | No |

# Define the chemicals compounds

Table 2 lists the compounds involved in the three proposed production routes, also providing heat capacity and molecular weight data when where necessary.

Table 2. Compounds required for the production systems proposed

|  |  |  |
| --- | --- | --- |
| **Component** | **Heat capacity (kJ/kg·K)** | **Molecular weight (g/mol)** |
| Proteins |  |  |
| Lipids |  |  |
| Sugar |  |  |
| Phenolics |  |  |
| Cellulose |  |  |
| Lignin |  |  |
| Hemicellulose |  |  |
| Starch |  |  |
| H2O |  |  |
| Ash |  |  |
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Table 3. Reactions related to anaerobic digestion and cogeneration plant

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| --- | --- |
| Reaction name | Reaction equation |
| Acetyl groups DA | -1 Acetyl groups → 0.33 CH4 + 0.57 CO2 + 0.1 Biomass |
| Cellulose DA | -1 Cellulose → 0.2 CH4 + 0.7 CO2 + 0.1 Biomass |
| Hemicellulose DA | -1 Hemicellulose → 0.15 CH4 + 0.75 CO2 + 0.1 Biomass |
| Lipids DA | -1 Lipids → 0.56 CH4 + 0.34 CO2 + 0.1 Biomass |
| Proteins DA | -1 Proteins → 0.33 CH4 + 0.57 CO2 + 0.1 Biomass |
| Starch DA | -1 Acetyl groups → 0.25 CH4 + 0.65 CO2 + 0.1 Biomass |
| CHP | -1 CH4 – 4 O2 → 2.75 CO2 + 2.25 H2O |

Table 4. Reactions related to hydrolysis and fermentation to ethanol

|  |  |
| --- | --- |
| Reaction name | Reaction equation |
| Cellulose acid-enzymatic hydrolysis | -1 Cellulose → 0.97 Sugar + 0.03 Cellulose |
| Hemicellulose acid-enzymatic hydrolysis | -1 Hemicellulose → 0.97 Sugar + 0.03 Hemicellulose |
| Starch acid-enzymatic hydrolysis | -1 Starch → 0.97 Sugar + 0.03 Starch |
| Ethanol fermentation | -1 Sugar → 0.44 EtOH + 0.42 CO2 + 0.13 Sugar |

Table 5. Utilities

|  |  |  |  |
| --- | --- | --- | --- |
| Utility  data | Parameter | Costs (€/MWh) | CO2 emissions (t/MWh) |
| Electricity | 120 | 0.33 |
| Heat | – | 0.24 |
| Chilling | 35 | 0.10 |
| Temperature data | Parameter | Temperature (ºC) | Costs (€/MWh) |
| Superheated steam | 140 | 29 |
| High pressure steam | 110 | 29 |
| Medium pressure steam | 100 | 29 |
| Low pressure steam | 95 | 29 |
| Cooling water | 15 | 29 |

Table 6. Potato Peel data

|  |  |  |
| --- | --- | --- |
| Composition | | |
| Components | %DM | |
| Proteins | 0.0253 | |
| Lipids | 0.0019 | |
| Phenolics | 0.0197 | |
| Cellulose | 0.0105 | |
| Hemi-cellulose | 0.0066 | |
| Ligin | 0.0025 | |
| Starch | 0.0952 | |
| Sugars | 0.0031 | |
| Ash | 0.0352 | |
| H2O | 0.8 | |
| Cost of products | | |
| Source | Quantity | Unit |
| Potato peel | 62 | €/t |
| Water | 0 | €/t |
| Protein | 1500 | €/t |
| Starch | 712 | €/t |

Table 7. NaOH in solution

|  |  |  |
| --- | --- | --- |
| Source name | NaOH (w) | |
| Cost input (€/t) | 6.95 | |
| Components | Component name | Composition fraction |
| H2O | 0.99 |
| NaOH | 0.01 |

Table 8. Information to define a necessary input of H3PO4 in solution

|  |  |  |
| --- | --- | --- |
| Source name | H3PO4 (w) | |
| Cost input (€/t) | 40 | |
| Components | Component name | Composition fraction |
| H2O | 0.98 |
| H3PO4 | 0.02 |

Table 9. enzymes

|  |  |  |
| --- | --- | --- |
| Source name | Enzymes | |
| Cost input (€/t) | 3036 | |
| Components | Component name | Composition fraction |
| Enzymes | 1 |

Table 10. air composition

|  |  |  |
| --- | --- | --- |
| Source name | Air | |
| Cost input (€/t) | 0 | |
| Components | Component name | Composition fraction |
| O2 | 0.21 |
| N2 | 0.79 |

Table 11. water input

|  |  |  |
| --- | --- | --- |
| Source name | Water | |
| Cost input (€/t) | 1.9 | |
| Components | Component name | Composition fraction |
| H2O | 1 |

|  |  |  |  |
| --- | --- | --- | --- |
| Grinding | | | |
| General information | | | |
| Parameters | Quantity | | Unit |
| Temperature (input) | 22 | | °C |
| Temperature (Output) | 25 | | °C |
| Reference cost | 0.263 | | M€ |
| Reference flow | 250 | | t/h |
| Exponent | 0.6 | |  |
| Reference year | 2017 | |  |
| Utility information | | | |
| Electricity | 0.016 | | MWh/ton |
| Conversion information | | | |
| Component | | Transfer factor | |
| Peel’s components | | 1\* | |

\* Grinding is a physical seperation. Therefore, split factors of components are equal to 1.

|  |  |  |
| --- | --- | --- |
| Centrifugation | | |
| General information | | |
| Parameters | Quantity | Unit |
| Temperature (input) | 25 | °C |
| Temperature (input) | 25 | °C |
| Reference cost |  | M€ |
| Reference flow | 250 | t/h |
| Exponent | 0.6 |  |
| Reference year | 2017 |  |
| Utility information | | |
| Electricity | 0.0005 | MWh/ton |
| Seperation information | | |
| Component | Transfer factor | Goes to |
| Fiber | 0.04 | Anaerobic digestion |
| 0.96 | Centrifugal Sieving |
| 0.04 | Coagulation |
| Proteins | 0.63 | Anaerobic digestion |
| 0.37 | Centrifugal Sieving |
| 0.63 | Coagulation |
| Starch | 0.01 | Anaerobic digestion |
| 0.99 | Centrifugal Sieving |
| 0.01 | Coagulation |
| H2O | 0.44 | Centrifugal Sieving |
| 0.56 | Coagulation |
| Lipids | 0.5 | Centrifugal Sieving |
| 0.50 | Coagulation |
| Phenolics | 0.5 | Centrifugal Sieving |
| 0.50 | Coagulation |
| Sugars | 0.5 | Centrifugal Sieving |
| 0.50 | Coagulation |
| Ash | 1 | Centrifugal Sieving |

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| --- | --- | --- | --- |
| Coagulation | | | |
| General information | | | |
| Parameters | Quantity | | Unit |
| Temperature (input) | 35 | | °C |
| Temperature (input) | 120 | | °C |
| Reference cost | 0.3906 | | M€ |
| Reference flow | 40 | | t/h |
| Exponent | 0.51 | |  |
| Reference year | 2007 | |  |
| Utility information | | | |
| Heating | 0.12 | | MWh/ton |
| Influent information | | | |
| Flow | Mixing coefficient | | Quantity (t/t input) |
| H2SO4 (96%) | H2SO4 | 0.98 | 1.1\*10-5 |
| Water | 0.02 |
| Seperation information | | | |
| Component | Transfer factor | | Goes to |
| Fiber | 0.04 | | Coagulation |
| Proteins | 0.63 | | Coagulation |
| Starch | 0.01 | | Coagulation |
| H2O | 0.56 | | Coagulation |
| Lipids | 0.50 | | Coagulation |
| Phenolics | 0.50 | | Coagulation |
| Sugars | 0.50 | | Coagulation |
| Fiber | 0.96 | | Centrifugal Sieving |

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| --- | --- | --- | --- |
| Filteration belt | | | |
| General information | | | |
| Parameters | Quantity | Unit | |
| Temperature (input) | 94 | °C | |
| Temperature (input) | 94 | °C | |
| Reference cost | 0.2 | M€ | |
| Reference flow | 0.01 | t/h | |
| Exponent | 0.54 |  | |
| Reference year | 2007 |  | |
| Utility information | | | |
| Electricity | 0.03 | MWh/ton | |
| Conversion information | | | |
| Component | Transfer factor | | Goes to |
| H2O | 0.261 | | Drying |
| Coag.Prot | 1.000 | | Drying |
| Proteins | 0.235 | | Drying |
| Starch | 1.000 | | Drying |
| Fiber | 1.000 | | Drying |
| Phenolics | 0.1 | | Drying |
| Lipids | 0.1 | | Drying |
| Sugars | 0.1 | | Drying |

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| --- | --- | --- |
| Rotry Drying | | |
| General information | | |
| Parameters | Quantity | Unit |
| Temperature (input) | 94 | °C |
| Temperature (input) | 35 | °C |
| Reference cost | 0.221 | M€ |
| Reference flow | 0.635 | t/h |
| Exponent | 0.65 |  |
| Reference year | 2007 |  |
| Utility information | | |
| Heating | 0.58 | MWh/ton |
| Seperation information | | |
| Component | Transfer factor | Goes to |
| H2O | 0.12 | Market |
| Coag.Prot | 1.000 | Market |
| Proteins | 1.000 | Market |
| Starch | 1.000 | Market |
| Fiber | 1.000 | Market |
| Phenolics | 1.000 | Market |
| Lipids | 1.000 | Market |
| Sugars | 1.000 | Market |

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| --- | --- | --- |
| Centrifugal Sieving | | |
| General information | | |
| Parameters | Quantity | Unit |
| Temperature (input) | 31.4 | °C |
| Temperature (input) | 31.4 | °C |
| Reference cost | 0.0558 | M€ |
| Reference flow | 21.18 | t/h |
| Exponent | 1.04 |  |
| Reference year | 2007 |  |
| Utility information | | |
| Electricity | 0.001 | MWh/ton |
| Seperation information | | |
| Component | Transfer factor | Goes to |
| H2O | 0.848 | Starch Washing |
| 0.152 | Belt Filtration (Fiber) |
| Proteins | 0.654 | Starch Washing |
| 0.346 | Belt Filtration (Fiber) |
| Starch | 0.900 | Starch Washing |
| 0.100 | Belt Filtration (Fiber) |
| Fiber | 0.141 | Starch Washing |
| 0.859 | Belt Filtration (Fiber) |
| Lipids | 0.928 | Starch Washing |
| 0.072 | Belt Filtration (Fiber) |
| Phenolics | 0.928 | Starch Washing |
| 0.072 | Belt Filtration (Fiber) |
| Sugars | 0.928 | Starch Washing |
| 0.072 | Belt Filtration (Fiber) |
| Ash | 0.923 | Starch Washing |
| 0.077 | Belt Filtration (Fiber) |

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| Starch washing | | |
| General information | | |
| Parameters | Quantity | Unit |
| Temperature (input) | 34.4 | °C |
| Temperature (input) | 45 | °C |
| Reference cost | 0.038 | M€ |
| Reference flow | 180 | t/h |
| Exponent | 0.35 |  |
| Reference year | 2007 |  |
| Utility information | | |
| Delta T | 10 degree |  |
| Seperation information | | |
| Component | Transfer factor | Goes to |
| H2O | 0.397 | Vacuum Filtration |
| 0.603 | Centrifugation |
| Proteins | 0.006 | Vacuum Filtration |
| 0.994 | Centrifugation |
| Starch | 0.900 | Vacuum Filtration |
| 0.100 | Centrifugation |
| Fiber | 0.051 | Vacuum Filtration |
| 0.949 | Centrifugation |
| Lipids | 0.006 | Vacuum Filtration |
| 0.994 | Centrifugation |
| Phenolics | 0.006 | Vacuum Filtration |
| 0.994 | Centrifugation |
| Sugars | 0.006 | Vacuum Filtration |
| 0.994 | Centrifugation |
| Ash | 0.006 | Vacuum Filtration |
| 0.994 | Centrifugation |

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| Vacuum Filltration | | |
| General information | | |
| Parameters | Quantity | Unit |
| Temperature (input) | 45 | °C |
| Temperature (input) | 45 | °C |
| Reference cost | 0.195 | M€ |
| Reference flow | 99.0 | t/h |
| Exponent | 0.7 |  |
| Reference year | 2007 |  |
| Utility information | | |
| Electricity | 0.0011 | MWh/ton |
| Seperation information | | |
| Component | Transfer factor | Goes to |
| Starch | 1 | Starch drying |
| Proteins | 0.5 | Starch drying |
| Fiber | 0.5 | Starch drying |
| H2O | 0.44 | Starch drying |
| Lipids | 0.5 | Starch drying |
| Ash | 0.5 | Starch drying |
| Sugars | 0.5 | Starch drying |
| Phenolics | 0.5 | Starch drying |

|  |  |  |
| --- | --- | --- |
| Starch drying | | |
| General information | | |
| Parameters | Quantity | Unit |
| Temperature (input) | 45 | °C |
| Temperature (input) | 55 | °C |
| Reference cost | 0.221 | M€ |
| Reference flow | 0.635 | t/h |
| Exponent | 0.65 |  |
| Reference year | 2007 |  |
| Utility information | | |
| Heating | 0.5854 | MWh/ton |
| Seperation information | | |
| Component | Transfer factor | Goes to |
| Starch | 1 | Market |
| Proteins | 1 | Market |
| Fiber | 1 | Market |
| H2O | 0.12 | Market |
| Lipids | 1 | Market |
| Ash | 1 | Market |
| Sugars | 1 | Market |
| Phenolics | 1 | Market |

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| --- | --- | --- |
| Hydrolysis | | |
| General information | | |
| Parameters | Quantity | Unit |
| Temperature (input) | 25 | °C |
| Temperature (input) | 85 | °C |
| Reference cost | 0.075 | M€ |
| Reference flow | 0.10 | t/h |
| Exponent | 0.53 |  |
| Reference year | 2006 |  |
| Utility information | | |
| Heating | 100 | MWh/ton |
| Amylase | 0.002 | Ton/ton starch |
| Stoichiometric Factors | | |
| Component | Coefficient | Converted to |
| Starch | 1 | Sugar |
| Cellulose | 1 | Sugar |
| Hemi-cellulose | 1 | Sugar |

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| --- | --- | --- |
| Ethanol fermentation | | |
| General information | | |
| Parameters | Quantity | Unit |
| Temperature (input) | 25 | °C |
| Temperature (input) | 35 | °C |
| Reference cost | 0.186 | M€ |
| Reference flow | 0.625 | t/h |
| Exponent | 0.719 |  |
| Reference year | 2020 |  |
| Utility information | | |
| Electricity | 0.00044 | MWh/ton |
| Stoichiometric Factors | | |
| Component | Coefficient | Converted to |
| Sugar | 0.1 | Biomass |
| 0.50 | EthOH |
| 0.4 | CO2 |
| Starch | 0.1 | Biomass |
| 0.50 | EthOH |
| 0.4 | CO2 |
| Hemi-cellulose | 0.1 | Biomass |
| 0.4 | EthOH |
| 0.5 | CO2 |
| Cellulose | 0.1 | Biomass |
| 0.3 | EthOH |
| 0.6 | CO2 |

|  |  |  |
| --- | --- | --- |
| Distillation | | |
| General information | | |
| Parameters | Quantity | Unit |
| Temperature (input) | 35 | °C |
| Temperature (input) | 82 | °C |
| Reference cost | 120 | M€ |
| Reference flow | 0.6 | t/h |
| Exponent | 2008 |  |
| Reference year | 120 |  |
| Utility information | | |
| Heating | 0.41 | MWh/ton |
| Seperation information | | |
| Component | Transfer factor | Goes to |
| Ethanol+water | 0.99 | Ethanol |
| 0.01 | Water |