

# DEFINE-MATTER

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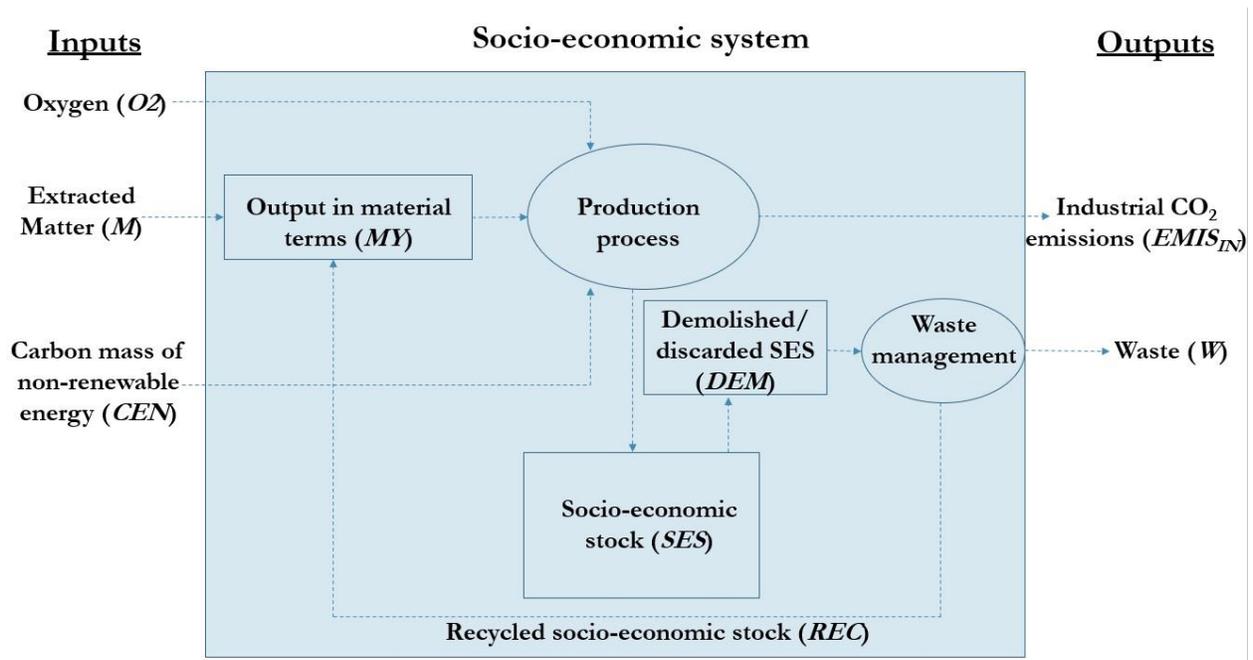
August 2019

[www.define-model.org](http://www.define-model.org)

## 1. Brief description

DEFINE-MATTER is a simplified module of DEFINE, which shows how economic growth leads to the extraction of matter and the generation of waste. The figure below outlines how the module works. When production takes place, a specific amount of matter is necessary (this is the 'output in material terms'). This matter can be either extracted from the environment or come from recycling. When matter is extracted, the material reserves (i.e. those volumes of matter expected to be produced economically using the existing technology) tend to decline.

**Figure 1:** Material inputs and outputs and socio-economic system



Non-renewable energy (that relies on carbon) is also necessary for the production process. Once the production has taken place, the material content of this energy is extracted to the environment in the form of CO<sub>2</sub> emissions.

The production process generates consumption and investment goods that are accumulated in the socio-economic system. The material content of these goods is called 'socio-economic stock'. A part of this socio-economic stock is demolished/discarded every year. Through waste management, a proportion of demolished/discarded socio-economic stock is recycled. The rest of it becomes waste that is discarded to the environment. Part of this waste is hazardous and can have negative effects both on the environment and the health of the population.

## 2. Module equations

$$\text{Output: } Y = Y_{-1}(1 + g_Y) \quad (1)$$

$$\text{Output in material terms: } MY = \mu Y \quad (2)$$

$$\text{Extracted matter: } M = MY - REC \quad (3)$$

$$\text{Recycled socio-economic stock: } REC = \rho DEM \quad (4)$$

$$\text{Demolished/discarded socio-economic stock: } DEM = prop SES_{-1} \quad (5)$$

$$\text{Socio-economic stock: } SES = SES_{-1} + MY - DEM \quad (6)$$

$$\text{Waste: } W = DEM - REC \quad (7)$$

$$\text{Stock of hazardous waste: } HWS = HWS_{-1} + haz W \quad (8)$$

$$\text{Material reserves: } REV_M = REV_{M-1} + CON_M - M \quad (9)$$

$$\text{Amount of material resources converted into material reserves: } CON_M = con_M RES_{M-1} \quad (10)$$

$$\text{Material resources: } RES_M = RES_{M-1} - CON_M \quad (11)$$

$$\text{Material depletion ratio: } dep_M = M / REV_{M-1} \quad (12)$$

## 3. Symbols and values

Symbol	Description	Value/calculation
<b>Parameters</b>		
$g_Y$	Growth rate of GDP	0.027
$haz$	Proportion of hazardous waste in total waste	0.04
$con_M$	Conversion rate of material resources into reserves	0.0015
$\mu$	Material intensity (kg/\$)	Calculated from equation (2)
$\rho$	Recycling rate	Calculated from equation (4)
$prop$	Proportion of socio-economic stock that is demolished/discarded	0.013
<b>Endogenous variables</b>		
$Y$	GDP (tillion US\$)	80.7
$MY$	Output in material terms (Gt)	52.11
$M$	Extracted matter (Gt)	Calculated from equation (3)
$REC$	Recycled socio-economic stock (Gt)	4.57
$DEM$	Demolished/discarded socio-economic stock (Gt)	17
$SES$	Socio-economic stock (Gt)	1339
$W$	Waste (Gt)	Calculated from equation (7)
$HWS$	Stock of hazardous waste (Gt)	14.09
$REV_M$	Material reserves (Gt)	Calculated from equation (12)
$CON_M$	Amount of material resources converted into material reserves (Gt)	Calculated from equation (10)
$RES_M$	Material resources (Gt)	$64.81 * REV_M$
$dep_M$	Material depletion ratio	0.02

## 4. Steps for simulating the module in R

**#Open R and create a new R script (File->New file->R script). Save this file as ‘Matter’ (File->Save as).**

**#Clear the workspace and identify how many time periods (T) you wish your model to run (once you write the commands, press ‘Source’)**

```
rm(list=ls(all=TRUE))
T<-104
```

**#STEP 1: For each endogenous variable, create a vector that has a length equal to the time periods. (Once you have written the commands, press ‘Source’.)**

### #Endogenous variables

```
Y<- vector(length=T)
MY<- vector(length=T)
M<- vector(length=T)
REC<- vector(length=T)
DEM<- vector(length=T)
SES<- vector(length=T)
W<- vector(length=T)
HWS<- vector(length=T)
REV_M<- vector(length=T)
CON_M<- vector(length=T)
RES_M<- vector(length=T)
dep_M<- vector(length=T)
```

**#STEP 2: Give values to the parameters (use the values reported in the table in Section 3).**

### #Parameters

```
for (i in 1:T) {
  if (i == 1) {
    for (iterations in 1:10){
```

```
g_Y<-0.027
haz<-0.04
con_M<-0.0015
mu<- MY[i]/Y[i] #Gt/trillion $ or kg/$
rho<- REC[i]/DEM[i]
prop<-0.013
```

**#STEP 3: Give values to your initial variables (use the values reported in the table in Section 3).**

### #Initial values

```
Y[i] <- 80.7 #trillion US$
MY[i]<- 52.11#Gt
M[i]<- MY[i]-REC[i]#Gt
REC[i]<-4.57#Gt
DEM[i]<-17 #Gt
SES[i]<- 1339 #Gt
W[i]<-DEM[i]-REC[i]#Gt
HWS[i]<-14.09 #Gt
REV_M[i]<-M[i]/dep_M[i] #Gt
CON_M[i]<-con_M*RES_M[i] #Gt
```

```

RES_M[i]<-64.81*REV_M[i] #Gt
dep_M[i]<-0.02

}
}

```

**#STEP 4: Write down the equations and run the model. (Once you have written the commands, press ‘Source’.)**

```

#Equations
else {

```

```

for (iterations in 1:10){

```

```

#Economy

```

```

Y[i] <- Y[i-1]*(1+g_Y)

```

```

#Matter, recycling and waste

```

```

MY[i]<- mu*Y[i]

```

```

M[i]<-MY[i]-REC[i]

```

```

REC[i]<-rho*DEM[i]

```

```

DEM[i]<- prop*SES[i-1]

```

```

SES[i]<-SES[i-1]+MY[i]-DEM[i]

```

```

W[i]<-DEM[i]-REC[i]

```

```

HWS[i]<-HWS[i-1]+haz*W[i]

```

```

REV_M[i]<-REV_M[i-1]+CON_M[i]-M[i]

```

```

CON_M[i]<-con_M*RES_M[i-1]

```

```

RES_M[i]<-RES_M[i-1]-CON_M[i]

```

```

dep_M[i]<-M[i]/REV_M[i-1]

```

```

}
}
}

```

**#STEP 5: Create a table to report the following variables: Y, W and dep\_M. Create also 3 graphs for these variables. (Once you have written the commands, press ‘Source’.)**

```

#Table

```

```

matrixname<-paste("Table")

```

```

assign (matrixname, (round(cbind(Y, W, dep_M), digits=4)))

```

```

plot(Table[1:T,c("Y")], type="l", xlab= "Year", ylab="Output (trillion US$)", xaxt="n")

```

```

axis(side=1, at=c(1,24,44,64,84, 104), labels=c("2017","2040","2060", "2080","2100", "2120"))

```

```

plot(Table[1:T,c("W")], type="l", xlab= "Year", ylab=expression("Waste"),xaxt="n")

```

```

axis(side=1, at=c(1,24,44,64,84, 104), labels=c("2017","2040","2060", "2080","2100", "2120"))

```

```

plot(Table[1:T,c("dep_M")], type="l", xlab= "Year", ylab="Matter depletion ratio", xaxt="n")

```

```

axis(side=1, at=c(1,24,44,64,84, 104), labels=c("2017","2040","2060", "2080","2100", "2120"))

```

**#Re-run the simulations by changing some parameters.**

**#First, assume that there is a decrease in the growth rate of output ( $g_Y$ ) from 0.027 to 0.01 in 2022**

Put the command below after '(i in 1:T) {'  
if ( i<6){g\_Y<-0.027} else {g\_Y<-0.01}

Delete the command:  
g\_Y<-0.027

(Once you have have done the above, press 'Source'.)

**#Second, assume that there is an increase in the recycling rate ( $\rho$ ) from 0.268 to 2\*0.268 in 2022, keeping the growth rate of output ( $g_Y$ ) equal to 0.027**

Put the command below after '(i in 1:T) {'  
if ( i<6){rho<-0.268} else {rho<-2\*0.268}

Delete the command:  
rho<- REC[i]/DEM[i]

(Once you have have done the above, press 'Source'.)