Goal

Boost the share of renewable energy from 25.7% of final energy consumption in 2013 to 31% in 2020 and 40% in 2030.
Approach:

**Success to the Successful**

- Success of A → Resources to A
- Success of B → Resources to B
- Allocation to A → Allocation to B

**Data:**
- Energy Sector data aggregated.
- Demand for energy is an exogenous parameter

**Main Unit:**
- **MTOE** (Million Tonnes of Oil Equivalent) - unit of energy defined as the amount of energy released by burning one tonne of crude oil

**Main Variables:**
- **TPES** (Total Primary Energy Supply) - total supply of energy that is consumed domestically, either in transformation or in final use
- **TFC** (Total Final Energy Consumption) - final consumption by end-users, i.e. in the form of electricity, heat, gas, oil products, etc.
- **Inclination to Invest** – an information delay as a function of energy cost and/or profit
**Model Development: Capital Investment**

**Explanation:** “Cumulative initial Capital” represents the available capital which flows into in the two subsystems, conventional and alternative energy-technology.

**Assumptions:** These flows are controlled by information feedback loops that symbolize the decision-making process in allocating the (financial) capital.

**Equations:**

Cum. Inv. Capital = INTEG (Capital Flow +"NR Inv."+"R Inv.", Init Cap)

R Capital = INTEG ("R Inv."-"R Depr.",Init R)

NR Capital = INTEG ("NR Inv."-"NR Depr.",Init NR)
Model Development: Utilization Rate

**Explanation:** “Cumulative Non-Renewable Utilization” represents the amount of energy expressed in mtoe produced based on the Capital.

**Equations:**

Cum. NR Util. = INTEG ("NR Util. Rate","Init NR Cum. Util.")


**Assumptions:** An endogenous variable expressing the amount of mtoe units produced per each unit of euro used, determines the Utilization Rate.
Model Development: Cost & Profit

**Explanation:** Cost are calculated based on the historical cost, the tax or subsidy applied based on the technology and the effect that technology, economy of scale and the learning curve has on cost.

**Equations:**

\[ \text{NR Cost} = ("\text{Init. NR Cost}" \times \text{Eff. of NR Learning on Cost} \times \text{Eff. of NR Util. Eff. on Cost} \times \text{Eff. of NR Scale Econ. on Cost}) + \text{Carbon Tax + Import Tariff} \]

\[ \text{R Cost} = ("\text{Init. R Cost}" \times \text{Eff. of R Learning on Cost} \times \text{Eff. of R Scale Econ. on Cost} \times \text{Eff. of R Util. Eff. on Cost}) \]

**Assumptions:** Cost structure is influenced by improvements in technology, economy of scale and the learning curve.
Model Development: Investment Inclination

**Explanation:** Inclination to invest in renewables is a ratio of the Renewables Profit per mtoe over the total profit generated by the two subsystems.

**Equations:**

Incl. Inv. $R = \text{Eff of Profit on Investment}$

Eff of Prof on Inv = $R \frac{\text{Profit per MTOE}}{(\text{R Profit per MTOE + NR Profit per MTOE})}$

NR Profit per MTOE = "Energy Market Price (MTOE)" - NR Cost

**Assumptions:** The model assumes that the allocation towards one of the energy-technology subsystems depends on an inclination to or a preference for a particular subsystem.
Model Development: Learning Curve

**Explanation:** The learning curve arises as workers and firms learn from experience. Accumulation of experience increases utility. Learning leads to reinforcing feedback.

**Assumptions:** The unit costs of production fall by a fixed percentage every time cumulative production experience doubles. NR has is reaching it’s peak learning, while R is just beginning.

**Equations:**

Eff. of NR Learning on Cost = ("Cum. NR Util."/"Init NR Cum. Util.")^NR Learning Curve Strength

NR Learning Curve Strength = LOG("NR Learning Curve Str. Fraction") + ((1 - "NR Learning Curve Str. Fraction") * NR L Switch), 2)
Model Development: Economies of Scale

**Explanation:** Spreading up-front development costs over a larger volume lower unit costs.

**Assumptions:** Unit costs fall as the scale of production rises. NR has largely already reached scale, and thus the effect is weaker on that side of the system.

**Equations:**

Eff. of NR Scale Econ. on Cost = (NR Capital/Init NR)^"NR Scale Econ. Strength"

NR Scale Econ. Strength" = LOG("NR Scale Econ. Str. Fraction" + ((1 - "NR Scale Econ. Str. Fraction") * "NR Ec. Switch"), 2)
**Model Development: Utilization Efficiency**

**Explanation:** The amount of mtoe per each unit of Euro increases as cost decreases.

**Assumptions:** Utilization Efficiency expressed as an endogenous variable changes over time due to the decrease of costs from the learning effect and economy of scale.

**Equations:**

"End. NR Util. Eff." = 1 / NR Cost
Policies: Carbon Tax

**Explanation:** Carbon Taxes of 5 Euro per Gtonne of Carbon began in 2008

**Equations:**

IF THEN ELSE(Time >= CT Start,  
("Euro/Gton"*"Poll. Prod. Perc.")*CT Switch,  
0 )

**Assumptions:** The effects of Carbon Taxes are aggregated, Kyoto Protocol taxation schemes are not accounted for,
Policies: Feed-in Tariff

**Explanation:** Feed-in Tariffs are subsidies for emerging technologies, values range between 50 Euro/MWh to 700 Euro/MWh per technology; Tariffs began in 1988 and are planned to end in 2017 due to swelling tariff deficit; expectations are grim for the impact that will have on Renewables

**Equations:**

\[
\text{IF THEN ELSE}(\text{Time} \leq \text{FT End}, \\
\quad \text{IF THEN ELSE}(\text{Time} \geq \text{FT Start}, (\text{Subsidy} \times \text{FT Switch}), 0), 0)
\]

**Assumptions:** Effects of Feed-in Tariffs are aggregated at one value over time
Policies: Investment Moratorium

**Explanation:** A moratorium halts investment in Conventional Energy capital, however allows for the utilization of existing capital until depreciated

**Equations:**

IF THEN ELSE(Time >= 2020, 1*M Switch, 1 )

**Assumptions:** Unlikely policy option, investment is halted, but could also be decreased slowly for a more realistic option
Simulation: Reference & Forecast

TFC Share

Time (Year)

Portugal Energy Market Share

Non-Renewable
Renewable
Green Growth Commitment
Simulation: Reference & Forecast

TPES Historical & Forecast vs. Output

- "Cum. Util. (TPES)" : Base
- MTOE Demand : Base

Portugal TPES

IEA Data
Simulation: Reference & Forecast

Utilization

Portugal TPES

IEA Data
Simulation: Stepping Up CO2 Tax
Simulation: Prolonging Feed-in Tariff

RTFC Share

TPES Historical & Forecast vs. Output

Utilization

- RTFC Share: Tariff Extension
- RTFC Share: CO2 Increase
- RTFC Share: Base
- "Cum. Util. (TPES)" : Tariff Extension
- "R Util. Rate" : Tariff Extension
- "NR Util. Rate" : Tariff Extension
- MTOE Demand : Tariff Extension
Simulation: Investment Moratorium
Simulation: Mixed Policies

R TFC Share

TPES Historical & Forecast vs. Output

Utilization

"Cum. Util. (TPES)" : Mixed
"R Util. Rate" : Mixed
"NR Util. Rate" : Mixed
**Goal**: Boost the share of renewable energy from 25.7% of final energy consumption in 2013 to 31% in 2020 and 40% in 2030.

**Base Case**: Current policies will not lead to hitting the goals set by the GGC based on this model’s assumptions. However, missing considerations may tip conditions towards achieving the goals.

**Lock-in**: Overcoming lock-in likely takes a quick and powerful action to reverse the effects of success to the successful as seen in the moratorium and mixed cases, however much more support will need to be provided in order to ensure a successful, and safe transition.
Limitations & Further Work

**Resource Depletion’s Impact on Prices:**
As Non-renewable sources of energy are depleted, prices will increase; this is not taken into consideration in the model.

**Saturation:**
If resource endowment remains fixed, there are diminishing returns for energy production. For renewables & non-renewables, sites with the highest potential or the most convenient location are exploited first.

**Energy Intensity:**
Energy intensity improvements from infrastructure & technology progress can decrease TPES supply from conv. energy; energy utilization is Renewables > Conventional, thus decreasing market share as efficiency increases.

**Disaggregating Capital Stocks:**
Each energy type, or for conventional, mature renewables and emerging renewables.

**Disaggregating Investment Dynamics:**
There is competition between each type of energy within renewables & the conventional system, as well as for Organizations large and small, and families.

**Technology R&D:**
R&D is internationally operated, and thus is not endogenous, however plays a very important part in decreasing the costs for renewable technologies in transport and energy.