REDEMO

A Resource Depletion Model

USER GUIDE

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ABSTRACT

REDEMO is a model created to facilitate first order calculations on potential depletion of a certain resource given historical data on production. It is based on Hubbert's logistic function that provides projections of expected production as well as peak year and available reserves. This guide provides an explanation on what is received as input and how can the output be interpreted. There are three key examples of resource depletion studies as well as a link to a YouTube video explaining the procedure. It is important to state the three key assumptions of the model, in prior. The latter include, current technologies available, maximum exploitation of the selected resource and solid historical data with absence of high discrepancies from year to year.

INPUT

The model receives as input a historical database of production of a certain finite resource. Provide a growth rate of production and the available reserves. It is important to provide the base year, that predicted production meets the actual one. At this point, it is important to state the three key assumptions of the model. The model considers current technologies and no technological advancement that might affect the future production. Furthermore, maximum exploitation of resources is considered as intentional restrictions in production (eg. for political reasons) will result in great errors in the predicted curve. Similar behavior is observed in the case of abrupt changes in production from year to year.

The model is based on Hubbert's logistic function which was originally used to match oilfield production. The same function is used for many other purposes, such as to model population growth and in epidemiology. Cumulative production is given by:

$$N = \frac{KN_0}{(K - N_0)e^{-r(t-t_0)} + N_0}, \quad (1)$$

where N is the estimated production, K refers to the proven reserves while N_0 is calculated so that modelled production at reference time, t_0 which is set to be the base year that matches the historical data value Q_D. The unconstrained growth rate of production is represented by r.
The first derivative of Eq. (1), which represents the rate of production, produces a bell-shaped curve:

$$Q_i^M = \frac{dN}{dt} = \frac{KN_0r(K-N_0)e^{-r(t-t_0)}}{\left((K-N_0)e^{-r(t-t_0)}+K\right)^2}, \quad (2)$$

where, Q_{iM} is the modelled production rate. The factors affecting the shape of the curve, are K and r and are defined by:

$$\frac{1}{N}\frac{dN}{dt} = r\left(1-\frac{N}{K}\right), \quad (3)$$

The above equation is solved using Eq. (2) to find N_0 for $Q_{2018D}=Q_{2018M}$. An error analysis was conducted to determine which curves adequately fit the historical data. To determine the quality of the data match, the following correlation coefficient is used:

$$E = \frac{\sum_i^n Q_i^M - Q_i^D}{\sum_i^n Q_i^D}, \quad (4)$$

where i labels the initial year and n the final, where there are available data. The E value calculates the deviation of predicted values from historical data. Q_{iD} and Q_{iM} refer to the historical and predicted data respectively, while K, r are determined with a try and error method, that returns the minimum value of E.

OUTPUT

The output of the model is a bell-shaped curve (Figure.1) that fits the historical data with minimum error and provides a projection of production for the following years. Apart from that, the peak production year is estimated according to the provided growth rate. Also, the S-shaped curve is provided (Figure. 2) that determines cumulative production (N) from the base year by solving Eq. (1).

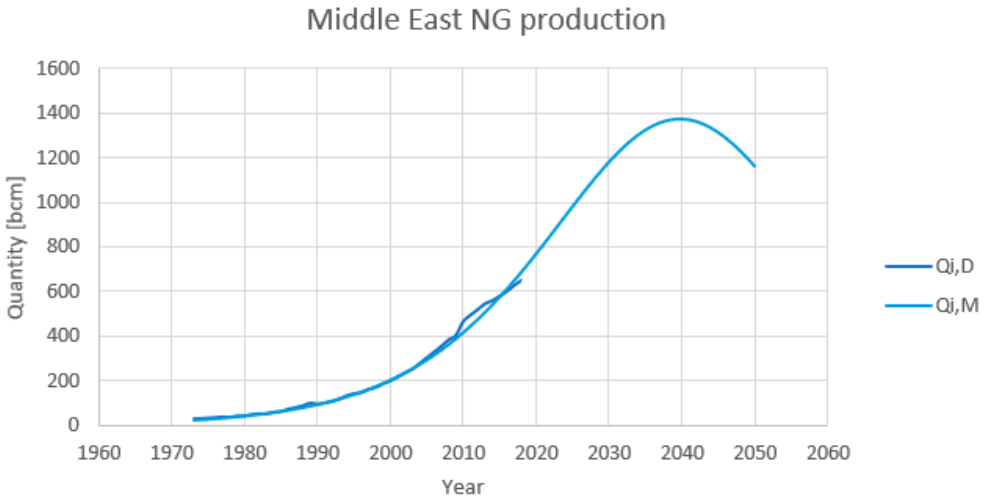

Figure. 1, Middle East Natural Gas production

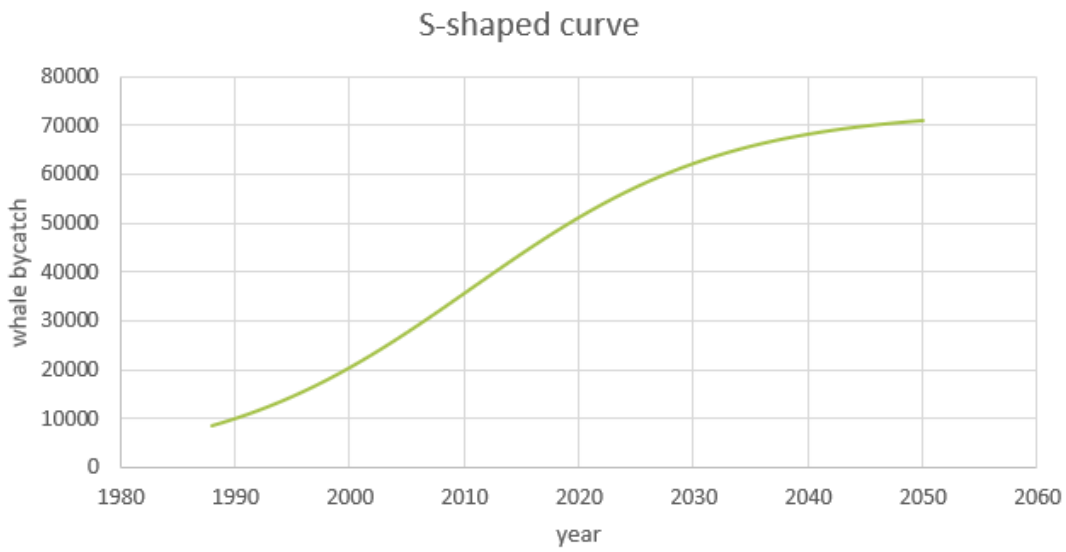

Figure. 2, Cumulative whaling.

Nomenclature

K	This value refers to the available reserves of the quantity in study
No	This value is calculated so that modelled production at reference year, t0, matches the historical data value Qi_D.
N	Cumulative production up to reference year, t0
Qi_D	Historical production data per year
Qi_M	Modelled production data per year
r	Growth rate of production
t	Time in years
t0	Reference year
E	Error coefficient
i	Year

References

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[2] A Hubbert analysis on natural gas production of the top producers. How the carbon budget is affected under unconstrained extraction. Karvounis Panagiotis, Martin J. Blunt, 5th International Conference on Environmental Pollution, Treatment and Protection, 2020, Lisbon, Portugal. DOI: 10.11159/iceptp20.154