How to achieve a low-carbon economy for the Netherlands in 2050? A System Dynamics model

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Background
SIM4NEXUS aims to address knowledge and technology gaps and thereby facilitate the design of policies within the Nexus. The project will deliver a Serious Game, a cloud-based, integrated tool for testing and evaluating policy decisions.

Objective paper
To analyse effects of implementing market-based policy instruments on the implementation of mitigation options

Introduction
The Netherlands have agreed to develop towards a low-carbon economy in 2050, which implies that greenhouse gas emissions (GHG) are 80-95% lower compared to the 1990 level. In 2015, total GHG in the Netherlands were 200 MtCO2-eq. per year, whereas the total GHG emissions declined as of 1990, the CO2 emissions were more or less stable, see Figure 1. In absolute terms, the Netherlands needs to diminish their GHG emissions to a level of at least 44 Mt CO2-eq. per year in 2050 (ECN and PBL 2015).

Figure 1. Greenhouse gas emissions development in the Netherlands 1990-2015 (CLO 2017)

Four main mitigation scenarios are discussed in the Netherlands, in addition to carbon levy:  
• Production of CO2-neutral electricity including bioenergy (RE scenario)   
• Energy savings (ES scenario)   
• Carbon Capture and Storage (CCS scenario)   
• Electrification (implicitly included in CO2-neutral electricity production)

Previous studies argued that all mitigation options will be required to achieve the low-carbon targets in 2050. However, policy instruments and behavioural changes were ignored. In all policy scenarios, we impose a carbon levy (on top of the relevant ETS price for carbon), affecting non-renewable energy only, and a subsidy on the relevant mitigation option given a neutral budget for the government.

Methods
We used a System Dynamic (SD) model which is top-down modelling approach to study complex behaviour in social sciences showing relationships between and within sub-systems. Our SD model includes the demographic economic system, the energy system and the environmental system of the Netherlands. Figure 2 shows the causal loop diagram of our SD model and its sub-models.

Data
Data of the model are derived from existing (policy) studies on carbon developments. The Business as Usual (BaU) scenario is comparable to reference scenario of the EU. In all policy scenarios, the low-carbon target (34 Mt CO2-eq.) was required, see table 1.

• The carbon levy is the major driver of the transition towards renewable energy production due to high price and cross-price elasticities of renewable energy demand.
• The carbon levy is the lowest in the RE scenario (subsidy on renewable energy production), while share of RE is the highest.

Energy savings and CCS are relatively expensive and require high subsidies for implementation.

Table 1. Simulation results in 2050 for policy scenarios (* accumulated over 2021 to 2050); Integrated policies scenario is based on 80% of subsidy included to RE, 10% to ES and 10% to CCS

Conclusions
• Market based policy instruments are potentially helpful with the implementation of mitigation options for GHG emission reduction.
• The scenario for subsidizing renewable energy showed the lowest carbon levy on top of the ETS price.
• For future research, land use and water boundaries for the transition towards a low-carbon economy will be taken into account.