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Expert views on low-carbon transition strategies for the Dutch solar sector: A delay-based fuzzy cognitive mapping approach

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Abstract: Despite recent growth in respective investments, the Netherlands is not expected to achieve its near-term renewable energy targets, indicating that policy design tends to overlook specific uncertainties and implementation risks. In the aim of supporting policymaking towards a low-carbon transition of the Dutch power sector with a focus on solar power, this study employs a stakeholder-driven approach based on fuzzy cognitive maps, while considering the notion of time. Results appear to strongly depend on expectations of future socioeconomic developments and show that stakeholders favour soft measures over financial incentives.

Keywords: decision support systems; solar energy; transition; Netherlands; fuzzy cognitive maps; policy

1. INTRODUCTION

Despite recent domestic progress in the energy and climate front, including inter alia a steady growth of investments in solar photovoltaics (PV) and near zero energy buildings (NZEB) (van Leeuwen, 2017), the Netherlands is not expected to meet its 2020 renewable energy target and respective commitment (ECN, 2017). In fact, in 2017, it was the only country among the European Union Member States underperforming in respect to its indicative Renewable Energy Directive trajectory (European Commission, 2017). Although the long list of measures included in the latest policy package of the Ministry of Economic Affairs are technically feasible, there exist a multitude of barriers jeopardising their successful implementation. These include policy instability, societal opposition, limited funding capacity, and ineffective spatial planning, and are usually difficult to incorporate in quantitative modelling processes.

In this context, alternative routes to supporting policy design are required, making use of the knowledge of and expertise in the possible impacts of these risks, embedded in various stakeholders (Nikas et al., 2017). The research question motivating this study, therefore, is "how can the Netherlands promote a decarbonisation pathway that is based on further diffusing solar power, from the point of view of various stakeholder groups of the Dutch economy".

Among a range of policy support tools, fuzzy cognitive maps (FCMs) present an opportunity for modelling the impacts of various policy instruments on a system, from the decision makers' and other stakeholders' perspective (Doukas et al., 2018). As a result, FCMs have been largely used in the literature for policy analysis (Vergini and Groumpos, 2017) as well as in a variety of scientific areas (Groumpos, 2010). In fact, FCMs have been used both in the domain of energy policy (e.g. Mpelogianni et al., 2015) and for the purposes of assessing risks and uncertainties associated with complex systems (e.g. Jamshidi et al., 2016), both of which are of interest to our research question. However, one of the concerns over the original methodological framework, which have recently mobilised efforts to evolve the FCM method (Vergini and Groumpos, 2016), concerns the reportedly poor definition of time (Kok, 2009), which however is critical to effectively underpinning policy recommendations.

The aim of this paper, therefore, is to implement the FCM methodological framework (Kosko, 1986), in a modified version so as to include the definition of time delay, in order to draw insights into experts' perceptions of alternative low-carbon transition strategies. The three examined strategies revolve around the diffusion of solar power, and concern the development of large solar parks, the promotion of decentralised power generation, and a focus on information campaigns and educational programs. The strategies comprise eight different policy measures, primarily drawn from the existing policy framework. The paper is structured as follows: Section 2 introduces the context of the case study, including a description of the policy measures and the scenario-driving uncertainties; Section 3 features the design of the model; Section 4 presents the simulation results and discusses the findings; and, finally, Section 5 briefly discusses the concluding remarks.

2. CONTEXT OF THE CASE STUDY

2.1 Policy instruments

In 2013, the Dutch government introduced the *Energy Agreement* for Sustainable Growth with industries, non-

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governmental and environmental organisations, trade unions and multiple other parties, which is considered an important step in the development of a low-emission economy (van Leeuwen, 2017). Parties, jointly responsible for the successful implementation of the agreement, agreed on short- to mid-term targets for energy efficiency and diffusion of renewables, as well as that long-term actions should be encouraged. In 2016, the Ministry of Economic Affairs intensified these efforts with the Energy Agenda (Ministerie van Economische Zaken, 2016), including additional measures for increasing the share of renewable energy technologies in the total energy generation and stimulate energy saving.

In the ground-mounted solar PV front, a subsidy on solar panel use was announced in 2008, later becoming part of the Ministry of Economic Affairs Stimulus Policy Renewable Energy Production (SDE), which targeted mainly wind power and biomass diffusion. Large projects are currently being incentivised through the *SDE+* subsidy mechanism (Oteman et al., 2017). The measure in particular subsidises the production of green electricity supplied to the grid, but soon proved too popular for solar PV, leading to depletion of the available budget (Verhees et al., 2013).

However, given the land requirements as well as the involvement of a multitude of technologies and refurbishments in the transformation of the building sector, both large-scale solar park development and rooftop PV installations require that effective spatial plans be developed by provinces and municipalities. Especially for the former, even if effective *energy planning in municipalities* is carried out, large-scale projects can nevertheless give rise to social conflicts. This further cultivates the need to mobilise *information campaigns* and engage the public towards encouraging behavioural changes. An example of societal incompliance in the Netherlands lies in the rejection of *smart metering*: wide-scale roll-out of smart meters aimed to facilitate nationwide monitoring and balancing efforts in the building sector; privacy violation fears and reported faulty operation of certain metering systems, however, created scepticism instead of acceptance of the, otherwise optional, measure.

Furthermore, small-scale solar panel installations on building rooftops are supported by the so-called *net-metering* policy, which incentivises households and small businesses to produce and use solar energy, by excluding them from energy taxes, VAT and the sustainable energy contribution levy over the self-generated and used energy. Due to its negative impact on the government's fiscal revenues, a series of respective changes to the regulatory framework have given rise to mistrust among citizens. In any case, given the currently loose building code (EPC), new buildings can still fulfil the building requirements, without installing solar panels. A *stricter building code* is perceived to be critical to the diffusion of rooftop solar PV installations.

Finally, there is a lack of high quality installation specialists; as a result, foreign experts are contracted to oversee large-scale project development processes. The shortage of installation experts and companies is also present at the residential sector, leading to significantly high salaries, as a response to high demand. *Education and integration programs* can be funded to mitigate this barrier and boost development at both fronts.

In this case study, therefore, three policy strategies are considered: a large-scale solar PV strategy (*P1. SDE+* and *P2. Energy planning for municipalities*), a decentralised generation strategy (*P3. Intensification of the Energy Agreement*, *P4. Net metering*, and *P5. Stricter building codes*) and an information- and education-oriented strategy (*P6. Smart meters*, *P7. Information campaigns*, and *P8. Education and integration programs*) that can boost both pathways.

The aim of the analysis is to capture how the strategies perform compared to one another, against different plausible future developments, from the stakeholders' perspective.

2.2 Uncertainties

Following extensive interviews with stakeholders, the following critical uncertainties, potentially giving rise to implementation risks, were identified. These uncertainties regarded issues of financial, societal and regulatory nature, with the latter having implications for the environment, and included:

- *U1. Public acceptance*
- *U2. Effectiveness of spatial planning and land use*
- *U3. Net-metering regulatory framework stability*
- *U4. Trust in government and policy*
- *U5. Funding capacity to invest in solar power*

Three scenarios were developed, describing different socio-economic developments. The first scenario describes a world with medium yet uneven economic growth, and modest institutional effectiveness in maintaining a stable regulatory environment; medium regulations in land use lead to satisfactory spatial planning for large solar projects, and fairly good societal participation and social cohesion levels cultivate a good opportunity for both pathways. The second scenario performs worse across all socioeconomic scenarios, in terms of societal factors, economic growth and priority for environmental issues, leading also to poor environmental planning and management; despite a weak international policy framework, national governments manage to create a steady, to some extent, policy framework, but there is hardly any regulation in land use and spatial planning. Finally, the third scenario describes a future of equally poor public acceptance, but faster economic growth, and highly regulated land use with a strong focus on spatial planning at the national and regional level; however, this scenario features limited attention to environmental vulnerabilities at the global level as well as high instability in the regulatory framework, also contributing to lower levels of trust and cohesion among the society. These descriptions help develop the initial state vectors of the three scenarios, i.e. the quantification of the uncertainties for each scenario (Fig. 1.) These scenarios are inspired by the narratives for the shared socioeconomic pathways SSP2, SSP3 and SSP4 (O'Neill et al., 2017).

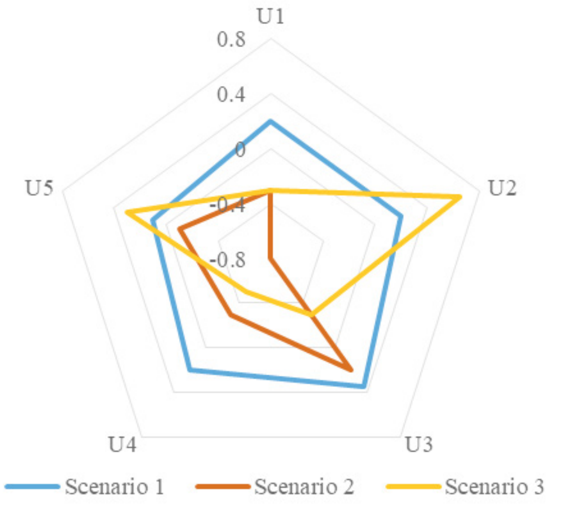

Fig. 1. Scenarios: Uncertainty values for each scenario.

3. MODEL DESIGN AND PARAMETERISATION

Following a detailed, interview-oriented stakeholder engagement process similar to the one discussed in Özesmi and Özesmi (2004), and extending the knowledge elicitation process to include the assessment of how soon each identified causal relation is expected to take place (time delay), the FCM model of the exercise is built (Fig. 2).

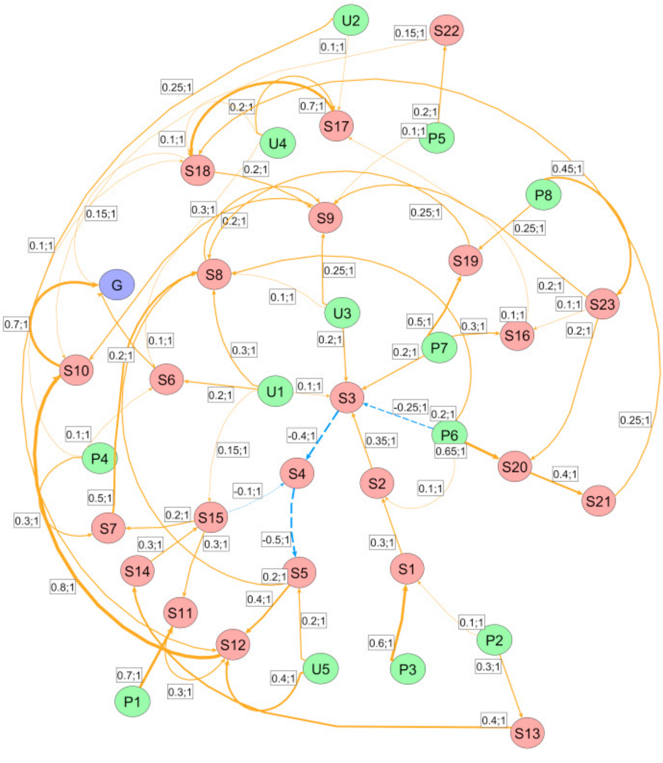

Fig. 2. FCM model: The fuzzy cognitive map of the Dutch solar sector, as designed in a stakeholder-driven process. Policies and uncertainties are depicted with green eclipses; system concepts with red eclipses; the end goal with a blue eclipse; positive causal relations with orange, constant arrows; negative causal relations with blue, dotted arrows; weights and time delays with a pair of two numbers divided by a semicolon.

Starting from the policy instruments and uncertainties, the identified causal propagation to the end goal, i.e. *G. Low-carbon transition*, included according to the engaged stakeholders the following system concepts: *S1. Cooperation of diverse stakeholder groups, S2. Long-term prospects, S3. Trust, S4. Investment uncertainty, S5. Investment and employment, S6. Energy saving and adoption of RES, S7. Financial incentives for households, S8. Investments in solar panels for roofs, S9. Upgrade of existing buildings, S10. Increasing the share of renewables, S11. Financial incentives for large-scale projects, S12. Investments in large-scale projects, S13. Consultation with regional and national stakeholders, S14. Assessing regional/local energy potential, S15. Formulating local policy, S16. Awareness for energy saving, S17. Acceptance and social compliance, S18. Behavioural change, S19. Public knowledge in RES, S20. Monitoring and reporting, S21. Control of utility bills, S22. Construction of new energy efficient buildings,* and *S23. Specialised courses for energy professionals*.

For simulating the model, a modified activation function (1) is used (Nikas and Doukas, 2016):

$$C_j^{(t)} = f\left(\sum_{i=1}^{n} C_i^{(t-lagij)} wij + C_j^{(t-1)}\right) \qquad (1)$$

Where, for iteration t, C_i and C_j are the values of concepts i and j at the end of the iteration, f is a threshold function, w_{ij} is the causal weight that concept i exerts on concept j, and lag_{ij} is the perceived time delay of this causal relation. This enables us to also consider the time dimension, by assuming that changes in some concepts mobilise changes in other concepts in a different time horizon than others, and translating each iteration step as a time period. By doing so, we expect that simulations will provide us with information not only on how well each strategy performs compared to one another, but also on how soon they are expected to achieve their potential.

The selected threshold function, for squashing the calculated values at the end of each iteration, is the hyperbolic tangent (2):

$$f(x) = \tanh(x) \qquad (2)$$

4. RESULTS AND DISCUSSION

The final results of the simulation are displayed in Fig. 3. It is evident that, for Scenarios 1 and 3, there is a weak yet consistent ranking among the three strategies. In particular, stakeholders appear to perceive that, when spatial planning in municipalities is effective and economic growth allows for investments in solar power, the third strategy (oriented on promoting public awareness through information campaigns, better monitoring of energy consumption, and specialised education and integration programs) is preferred, closely followed by a policy strategy focusing on the built environment. Interestingly, on the other hand, in a less optimistic scenario in terms of funding capacity and spatial planning effectiveness, a focus on large-scale solar PV projects not only outperforms the other two strategies from the stakeholders' perspective, but is the only one managing to overcome the adverse socioeconomic environment, despite a more stable regulatory environment that clearly boosts investments in buildings. This finding indicates that, for the given system dynamics captured by stakeholders in this FCM study, as we shift towards a future that is more challenging across all socioeconomic dimensions, it is the social axis that has the decisive impact on the policy framework.

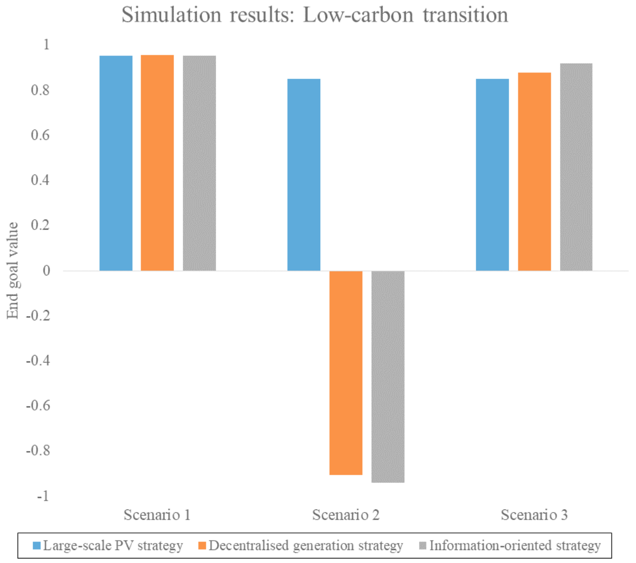

Fig. 3. Results: The FCM simulation results for the three strategies, for all three scenarios.

By delving into each iteration step of the simulation process for each one of the three scenarios, the most interesting finding lies in Scenario 3. It is evident from Fig. 4 that, although the education- and information-oriented policy strategy appears to eventually outperform the other two strategies as previously discussed, the value of the low-carbon transition end concept features a noteworthy progress: initially, it outranks the other two strategies and, then, it becomes negative, before finally converging to a better state than in the other two strategy simulations. From a policy perspective, this can be translated into the stakeholders' expectations that a policy focus on measures aiming to inform, educate and provide better control of utility bills to the public features a significant delay in contributing to the desired behavioural change. This, in turn, may be perceived as an indication that a soft measure-oriented strategy is not expected to address the climate mitigation and adaptation challenges as well as the adverse socioeconomic conditions in the mid-term; in the long-term, however, it proves to be a more sustainable pathway, from the experts' perspective. This can be largely explained by the considered time delays of the perceived effects of these policy instruments, as opposed to the more immediate yet weaker impact of harder, incentive-oriented strategies.

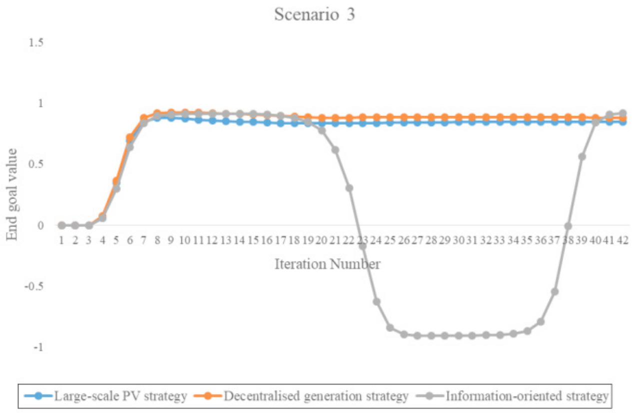

Fig. 4. Scenario 3 FCM simulation results for "G: Low-carbon transition": Intermediate values for the end goal concept, after each iteration, for all three policy strategies.

In order to better understand the effect of the consideration of perceived time delays in the FCM methodological framework, simulations for Scenario 2 were carried out for a second time, by disregarding time lags in the activation function. Although the converging state vector, across the whole model, does not change (Nikas and Doukas, 2016), there are differences with respect to the timing of the effect of each policy strategy. In particular, when ignoring the notion of time, aside from a faster convergence to the final state, the preferred (for this scenario) large-scale solar project strategy appears to be outperformed by a strong focus on the built environment in the near-term, before eventually outperforming the other strategies as well as managing to address the significantly adverse socioeconomic conditions (Fig. 5). In contrast, the employed approach shows that stakeholders view the large-scale project strategy as preferable both in the near- and in the longer-term (Fig. 6).

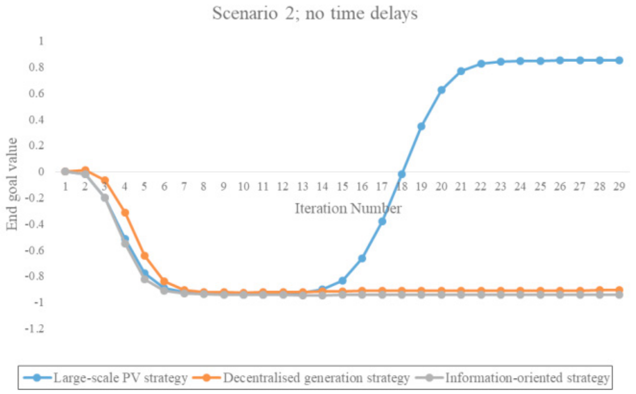

Fig. 5. Disregarding time delays: Scenario 2 simulation results for "G: Low-carbon transition", without considering time lags in the simulation process.

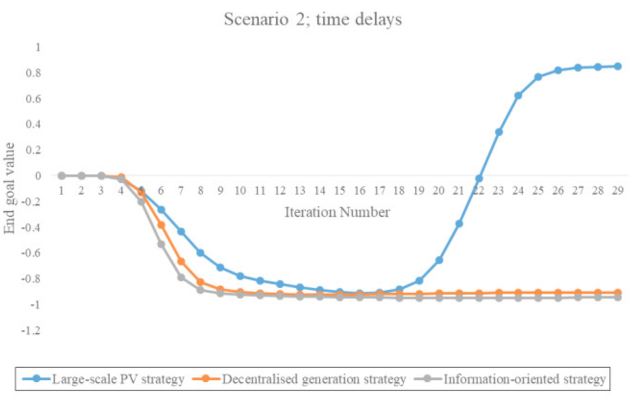

Fig. 6. The effect of time delays: Scenario 2 simulation results for "G: Low-carbon transition", while consdiering time lags.

5. CONCLUSIONS

Despite its non-quantitative nature and the consequent need to carefully translate its outcomes on a comparative basis, fuzzy cognitive mapping can help policymakers understand their knowledge domain and therefore provide them with fruitful insights into policy strategies, based on their experience and expertise. In this study, a modified version of the original FCM framework is employed to also consider the perceived effect of time delays of the identified causal model.

By revisiting our original research question, we can conclude that, from the involved stakeholders' perspective, a strong focus on behavioural change-oriented soft measures constitutes a more sustainable, yet less timely, pathway to transforming the solar power sector and promoting the desired low-carbon transition in the Netherlands, than financial incentives-driven measures for either small- or large-scale solar PV projects. It should, however, be noted that this is not the case in a scenario describing a world with little societal participation and cohesion, despite inadequate funding capacity or effective spatial planning, in which large-scale projects appear to outperform both other strategies.

Future prospects of this study involve the assessment of time using other techniques in the literature (e.g. Biloslavo and Dolinšek 2010; Mourhir et al., 2016), which have different implications for the converging state vector, as well as the use of datasets in combination with stakeholder knowledge (e.g. as in Papageorgiou et al., 2004). Efforts towards this direction can be found in the integration of the proposed FCM approach with quantitative systems modelling frameworks, as suggested by Doukas et al. (2018).

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