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Towards actor-based Neo-Carbon scenarios

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Preface

This document is part of reporting of the results achieved during the first funding period of the *Neo-Carbon Energy* project Work Package 1: *Neo-Carbon Enabling Neo-Growth Society – Transformative Energy Futures 2050*. The first funding period was run between 1.7.2014-30.6.2016.

This document describes the actor analyses research conducted in *Task 1.5: Market design and actor analysis*. The goal of the sub-task reported is to *recognize the actors, who would make the change in Neo-Carbon scenarios and interconnections between different actors.*

As a key focus, methodologies and plans to tackle actor analysis in Neo-Carbon project framework, where a rich assortment of scenario and analysis methods are used in several work packgages, are discussed.

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Research group of WP1 of the NEO-CARBON ENERGY Project

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Executive summary

What is this study about?

A move towards 100 % renewable energy based system highly based on solar and wind as a high-level topic of the Neo-Carbon Energy (NCE) project is clearly linked with behavior of different actors in society. Actor analysis for Neo-Carbon project is motivated by arisen need for "identifying & adding actors" to Neo-Carbon scenarios.

The NCE scenarios are analyzed and produced by several approaches, however, often lacking a thorough consideration of actor viewpoint. To illustrate this in simple terms, a question *what* can change is often analyzed by techno-economic scenarios and traditional energy system modeling work. In actor analysis, the viewpoint is first turned towards a question *who* can change. Consequently, this has an impact on how society re-organizes. Generally, actor analysis is also needed for any kind of real dissemination, e.g. for policy recommendations and/or development of an action plan. The actor analysis can reveal influences in actors' goals, strategies, and options.

As there is no "textbook method" available to be directly applied in NCE analysis, work in Funding Period 1 (FP1) concentrated on analysing the feasibility of different methods based on draft materials and discussions. Thus, importantly, at FP1, the goal of the work was not to deeply analyse the draft versions of source materials from the perspective of identified actors.

What methods were tested for Neo-Carbon actor analysis?

This report describes the efforts implemented during 1st funding period of the Neo-Carbon project. Based on research conducted, suggestions for key actors in the scenarios and their significance were identified. These main efforts are based on:

- Word analysis of Work Package 1 (WP1) scenario storylines by UTU/FFRC based on foresight methodologies
- Exploration of scenario storylines
- Collaboration with the Work Package 3 (WP3) research on business cases.

In addition to these experiments, approaches for quantification in actor analysis related problems were preliminarily analyzed based on review of external studies whose field is near to NCE.

What did the tests tell on actors of the Neo-Carbon scenarios?

In the *Radical Startups* scenario, startups, companies, investors, workers, cities, and entrepreneurs are suggested as key actor types. Reflecting to scenario description, these groups can be seen as potentially having a role in the field of small-scale and innovative energy solutions, for example. Media, freelancers and consumers are suggested as categorized as other actors identified.

Value-driven techemoths scenario considers large technology companies "Techemoths" as main actors of the development as Google, Facebook, Apple and Samsung are mentioned as exemplary of this type of companies in the studied text. It seems natural to assess that strategies and actions of these type of giant companies strongly outline the development towards Neo-Carbonized world in the scenario.

In *Green DIY engineers* scenario, relatively few actor types – however, potentially high number of individuals - are identified in comparison to others. As the nature of the scenario as being driven by self-made and communal efforts, local communities, people, and "DIY engineers" are suggested as key influencers in the scenario.

In *New consciousness* scenario, global systems face a radical transformation and as the actors identified are most diversified, key single actors running the transformation are more difficult to identify on a basis of stakeholder matrix. However, the role of international collaboration and global systems is assessed as evident. International organizations can be seen as enablers of this development.

In parallel to word analysis based experiment, collaboration was made with WP3 research to include and utilize results from concrete business cases in the actor analysis. The aim was to identify the key actors of Neo-Carbon energy system based on WP3 expertise and results on profitability of different Neo-Carbon concepts. As a first result, the following "actor archetypes" were identified with different strategies and drivers on the energy system transition towards Neo-Carbon type.

- Big, established companies actively keeping the same market in an environment of holistic system change (e.g. moving away from fossil fuels).
- Startups, "better product" as a driver. Young, agile companies. Example: renewable wind and solar fields and associated Power-to-gas technology.
- Industrial passive adapters – the primary product being elsewhere and the Neo-Carbon technologies are not the main focus in operations.
- Do-It-Yourself. For example, small-scale inventors with a passion on technology, demonstrations, and new gadgets. Single-house owners in central role; the distinction between slow adapters and forerunners.

Could agent-based modeling work as a quantitative approach?

To consider approaches for quantification in actor analysis related problems, agent based modeling tools were explored and studied based on external literature. Agent-based models are known to be computationally heavy and greedy for detailed data the example presented confirms these features. On the positive side, the models can usually be defined with easy-to-understand concepts and the decision-making logic of the agents can at best be constructed so that they resemble those of everyday life.

Especially related to NCE field, the agent-based method was found to have recently been utilized in cases with a high number of stakeholders and decision-makers such as modelling of penetration of small-scale PV panes in districts, which was reviewed as an example. The main issues in describing individual agents were models of consumer adoption process and the influence of consumer heterogeneity. Also, structures of consumers' social networks were found out to having a great influence and having been widely studied in agent-based literature.

The way forward

Based on literature reviewed, actor analysis methods were identified to often being based on interviews, workshops, focus group discussions, questionnaires and other qualitative methods. Often, the application of these methods concerned local and more specified questions rather than global megatrends. Thus, further collaboration with the NCE business case studies – and potentially the actual identified key actors - might provide with the most promising opportunities in deepening the actor analysis.

List of abbreviations

ABM	Agent-based modelling
CHP	Combined Power and Heat
DIY	Do-It-Yourself
EU	European Union
FFRC	Finland Futures Research Centre
FP1	Funding period 1 of the Neo-Carbon Energy project (2014-2016)
ICT	Information Communications Technology
IRENA	The International Renewable Energy Agency
LOHAS	Lifestyles of Health and Sustainability
LUT	Lappeenranta University of Technology
NCE	Neo-Carbon Energy
NGO	Non-Governmental Organization
P2G	Power-to-Gas
pbc	Perceived behavioural control
PV	Photovoltaic
RES	Renewable Energy Sources
TIMES	The Integrated MARKAL-EFOM System
TU Delft	Delft University of Technology
UN	United Nations
UTU	University of Turku
VRE	Variable renewable energy
VTT	VTT Technical Research Centre of Finland Ltd.
WoM	word-of-mouth
WP	Work Package

1. Introduction

A move towards 100 % renewable energy based system as a high-level topic of the Neo-Carbon Energy project (NCE) has its technological and economical drivers and barriers. These questions are tackled In Neo-Carbon project by several quantitative and qualitative scenario approaches in different work packages. Generally, quantitative scenario results are e.g. based on techno-economic models, optimizing feasible pathways towards set emission reduction or simulated behaviour of 100 % RES based energy system. Qualitative scenario results, on the other hand, are based on foresight methods and can widely encapsulate societal aspects of transformative futures.

Questions sometimes popping up when presenting optimizing model-based (backcasting) scenarios is: So what? What is the significance of results from actors' perspective? What should be done with all the information based on extensive models? How can the results be transferred in robust action plans with needed stakeholders and other actors? Lack of actors and governance is a confessed shortcoming of backcasting scenarios answering how to reach a predefined target. The changes towards 100% RES (renewable energy sources) based system, however, obviously concern multiple stakeholders.

Development of *actor analysis* or *actor-based Neo-Carbon scenarios* is motivated by "identifying & adding actors" to Neo-Carbon scenarios to shed light on the questions above. Actor analysis is also needed for any kind of real dissemination, e.g. for policy recommendations and/or development of an action plan. The actor analysis can reveal influences in actors' goals, strategies, and options. Target of the actor analysis study in Neo-Carbon project is to complement and enable an efficient use of qualitative and quantitative scenarios as well as business case studies.

In the end, the target outcome of the actor analysis supports the goals of the project on following aspects towards the Neo-Carbon world:

- We will have a robust action plan with needed stakeholders and other actors
- Both technological and societal as well as policy dimensions are included
- Pathways to Neo-Carbon Finland and other regions
- Business opportunities for Finnish companies

Actor-based scenarios aim at identifying key actors, timelines and barriers for Neo-Carbon Finland. This report describes the efforts implemented during 1st funding period of the Neo-Carbon project. Furthermore, we describe the forthcoming steps needed in order to develop concrete action plans in subsequent phases of the project.

In latter part of the 1st funding period of the Neo-Carbon project and after exploring and testing methods to identify and add actors, *agent-based modelling* was identified as intriguing approach to explore the actor analysis quantitatively. Especially, tackling social interactions quantitatively is something additional to typical techno-economic approaches. Thus, the literature and methodology were reviewed to explore the feasibility of agent in context of future "Neo-Carbonized" energy system. Findings of the agent-based analysis considerations are reported in Chapter 4.

2. Actor analysis for Neo-Carbon project

2.1. Background and sources of information

Actor analysis was studied as a method to identify and add actors to Neo-Carbon scenarios. Most relevantly, lack of actor viewpoint is a confessed shortcoming of traditional quantitative techno-economic models (Wangel 2011). Building on this set-up, the following questions where approached.

- What actor analysis methods are available and could be most useful?
- How to develop and apply them in the Neo-Carbon project?

Actor analysis was explored as a means of developing quantitative scenario analysis and other results more instrumental. Also, actor analysis was explored as a potential method for the Neo-Carbon project scenario framework for better collaboration between different research groups and research methodologies.

In Neo-Carbon project, an extensive amount of scenario results and techno-economic information on feasibility and transformation towards a world of 100 % renewable energy are produced in work packages WP1, WP2, and WP3. The Work Packages, thoroughly introduced in the project plan, are presented in *Table 1*.

Table 1. Work Packages of the Neo-Carbon project to be utilized in actor analysis and their contents in rough terms.

	WP name	WP Contents
Work Package 1	*Neo-Carbon Enabling Neo-Growth Society – Transformative Energy Futures 2050*	Transformative scenario sketches and input for other WPs (e.g. Futures clinique).
Work Package 2	*National energy economy and systems*	A variety of quantitative energy system models from VTT and LUT used in the project with their different needs and applicability.
Work Package 3	*System integration, value chains, business cases*	Process and concept related data

To enable the results being consistent and the WPs being supporting each other, the "best" way to organise the interaction was analysed during the first funding period. This was started by reviewing earlier attempts to link socio-economic storylines and multiple quantitative models. Actor analysis was identified as a potential method in Neo-Carbon project scenario framework for better collaboration and use of scenarios.

Actor analysis has its complementing function to the traditionally produced quantitative scenario results as an obvious benefit. To illustrate this in simple terms, a question *what* can change is often analysed by techno-economic scenarios and traditional energy system modeling work. In actor analysis, the viewpoint is turned towards a question *who* can change. After identifying *who*, a natural direction to continue would be analysis of interpreting what do these changes imply.

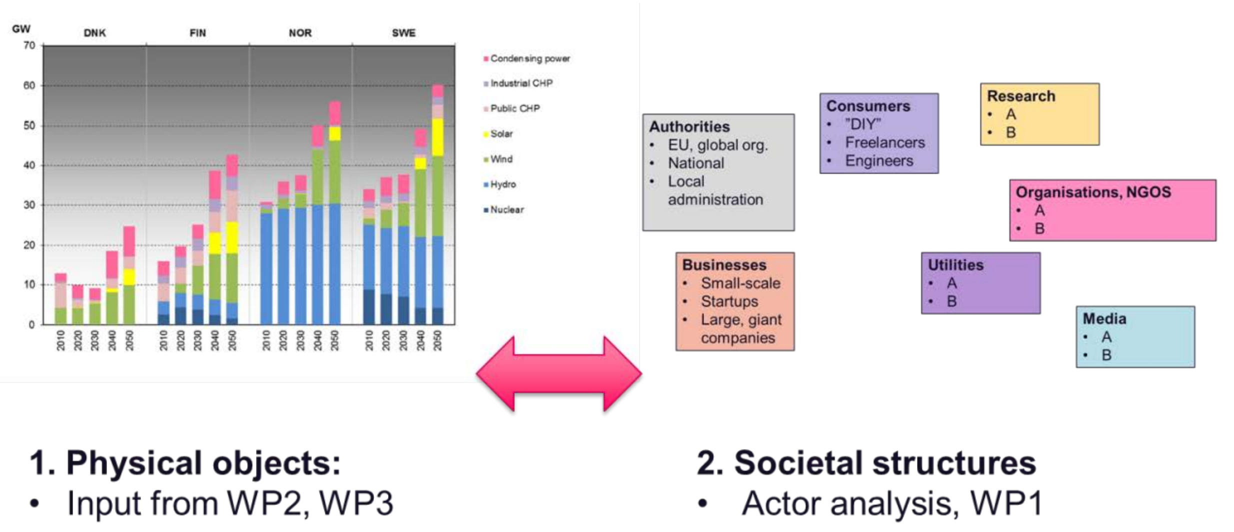


Figure 1. Objects of change (source of the left-hand side-figure: E. Pursiheimo, VTT).

Figure 1 demonstrates the Neo-Carbon scenario framework and contents of this report. The left-hand-side figure presents a typical result of quantitative techno-economic scenario model, here obtained from VTT-TIMES modelling framework. This example demonstrates the electricity production capacity development in the Nordic countries under defined conditions or targets until 2050. There is a rich assortment of this type of quantitative techno-economic analysis results conducted in Neo-Carbon project.

Right-hand side of *Figure 1* demonstrates actors potentially involved in actually making the change suggested by the techno-economic calculations happen. Potentially, the key actors can involve further specifiable researchers, consumers, authorities, organisations, non-governmental organisations (NGOs), various industrial actors, just to name a few. However, a description and analysis of actors involved is often lacked from studies building on methodologies based on techno-economic assessments and modeling. **This report is about considering systematic methodologies for actor analysis and their application Neo-Carbon project to enhance and make the project results more utilizable**.

2.1.1. Scenario approaches and definitions

A term *scenario* is referred to in several contexts when scenario build-up and application are considered. Each scenario approach has its role and valuable contribution in discussing feasibility and potential of Neo-Carbon type energy system development. While acknowledging there are also several other possible classifications available, *Figure 2* presents one classification of scenarios.

The approaches for scenario analysis in Neo-Carbon project include quantitative techno-economic pathways with different energy system and simulation models, which are mainly developed in Work Package 2. Work Package 1 scenarios present mainly qualitative storylines and are developed based on foresight and futures studies methodologies, e.g. Futures Clinique process.

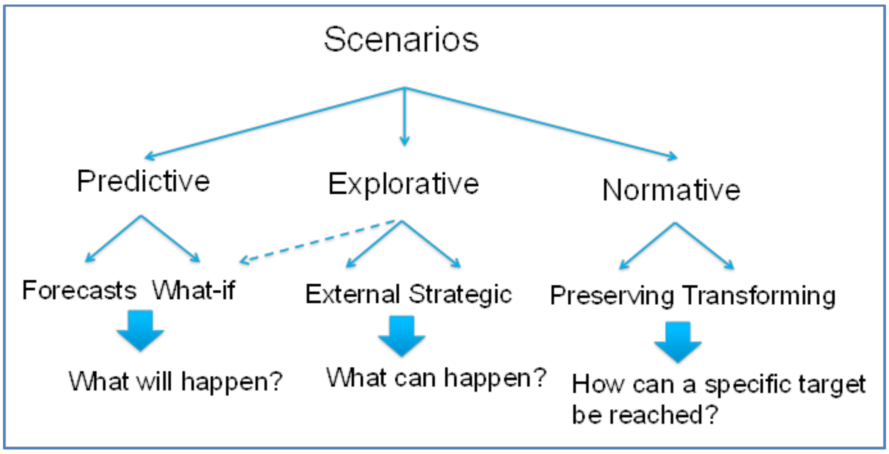


Figure 2. Neo-Carbon scenario typology with three categories and six types (modified from Börjeson et al. 2006).

Generally, predictive forecasts and what-if scenarios are short-term oriented. Thus, it is natural that these approaches are not emphasized in the Neo-Carbon project dealing with major long-term transformations compared to current energy system. However, it has to be kept in mind that as energy system investments may have lifetimes of even dozens of years, also short-term is relevant timeframe when action plans are considered for changes of large magnitude.

Both normative and explorative are considered in the Neo-Carbon project. The target of normative preserving Neo-Carbon scenarios can be e.g. assessing a pathway towards 80-95% GHG reduction by 2050 or max. RES share. *Backcasting* is a normative scenario approach which can be characterised on basis of two central elements: the development of images of desirable futures, and the elaboration of pathways of transition connecting these futures to the present (Robinson 1990, according to Wangel 2011).

In quantitative backcasting scenarios a model (e.g. TIMES) finds (i.e. optimizes) the cost-optimum path. In explorative Neo-Carbon scenarios, maximum share of renewables is researched. In quantitative explorative (EnergyPLAN, etc.) scenarios the model simulates how the system works under such circumstances. New robust decision making tool helps to understand the link between decision making by different actors and quantitative scenarios (i.e. uncertainties) (Forsström 2016). These quantitative types of workpieces are conducted in WP2 of the NCE project.

Qualitative WP1 scenarios are transformative by definition, with each of the scenarios providing insights on how a future, neo-carbonized world might be realized in radically different ways. Especially, the WP1 scenarios built on foresight and futures study methods introduce numerous societal changes not easily addressed by quantitative WP2 models. Scenarios developed in WP1 of the Neo-carbon project: *Radical startups, New Consciousness*, *Value-driven "Techemoths"* and *Green DIY Engineers* are thoroughly documented in several UTU/FFRC publications, e.g. Heinonen et al. (2015).

A transition to Neo-Carbon society needs a transformation into a structurally different system (i.e. energy, industrial, community, economical). Hence, a challenge in WP1-WP2 linkage is identified. In quantitative modelling, the structure of the transformative system is often rejected because trends are broken and the current structure is part of the problem. Similar restriction does not concern qualitative methods, on the contrary. Governance and institutional issues can support closer synthesis of qualitative and quantitative scenario building.

To make Neo-Carbon scenarios more instrumental in supporting policy making process, scenario method should be carefully considered for modelling purposes (i.e. explorative, normative,...). Quantitative studies should address the political and institutional preconditions and/or constraints for materialising the Neo-Carbon futures. *Actor-based scenarios and actor analysis* has been identified as a tool for supporting these targets.

Table 2 presents a general characterization of the strengths and weaknesses of the qualitative and quantitative scenario approaches.

Table 2. Strength and weaknesses of scenario approaches based on Trutnevyte et al. (2014).

	Qualitative scenarios/storylines **(”WP1-type” results)**	**Quantitative model-based scenarios** **(”WP2-type” results)**
Strengths	• Developed through engagement of experts and stakeholders, combining multiple perspectives and sources of expertise • May lead to novel and creative way of thinking about the future that go beyond modelling insights • Key for communication the results of scenario exercises. • Accessible and memorable to broad audience. • Storylines can encapsulate a number of softer and subtler aspects (institutional changes, behaviour) etc. difficult to model	▪ Satisfying the need for numerical values, like costs, emissions, and use of natural resources ▪ Based on empirical data, physical laws, principles of economics and state-of-the-art knowledge about the technological systems, trade and environmental processes ▪ Storylines maybe quantified to pathways with milestones and branching points
Weaknesses	• Potentially detached from reality - difficulties in confirming feasibility of storylines • Combining multiple views of stakeholders: potentially biased, not reproducible, not transparent	• Difficulties in capturing the social and institutional aspects, breaking points, non-linear trends (e.g. surprises and “black swans”): behaviour and acceptance, governance, organisational or institutional changes

2.1.2. Business cases

Potential synergies and disadvantages of applying different new concepts to existing applications on system level are identified in WP3. According to project plan, the approach selected is to use business cases which will be studied in detail. These business cases will then form the core of the new pieces on the whole national level model. Technology and business portfolios will be evaluated through the following tentative business case studies:

- Electricity production
- Transportation
- Farm or forest owner
- Combined heat and power (CHP) production
- Forest and other industrial hybrids

Business cases form a potential source of information for actor analysis. That is, as new concepts are techno-economically analysed, detailed result information on barriers, key drivers, etc., can be used. In-depth studies on new concepts potentially accumulate into knowledge on actors.

2.1.3. Potential actor types

In earlier energy scenario projects (e.g. Koljonen et al. 2014), several actors have been identified. Below, based on experiences, an initial list of potential actors is provided. The list below is based on actor groups considered to be represented in participatory and interactive process of build-up of low-carbon energy scenarios.

- Research
- Authorities (regional, national, European/Global organizations)
- Organisations, NGOs
  - Industry organisations
  - Labour market organisations
  - Environmental organisations
  - Youth alliances
  - Development organisations
- Business actors (SMEs, large companies)
- Consumers (average, LOHAS[1])
- Media

In addition to more generic actors described above, IRENA (2015) discusses the change of stakeholder roles especially from the power sector viewpoint, especially variable renewable energy (VRE) integration (*Table 3*, *Table 4*). Interestingly, not only stakeholders are listed but also their roles are briefly described. Furthermore, some new stakeholders are identified in

[1] Lifestyles of Health and Sustainability

Table 4. Here, a lot of new actors and activities seem to be resulted from increasing small-scale generation and the associated actions required by electricity system management. These listings provide with good sources for "first guesses" for key actors in Neo-Carbon actor analysis. Transmission and Distribution system operators in electricity supply system provide with one step more specified actor group for energy and Neo-Carbon applications. Tackled by regulators, market design is an example of relevant activity, also studied in WP1 of the Neo-Carbon project.

Table 3. Existing stakeholder roles that will require changes for VRE integration (Source: IRENA 2015).

Existing stakeholders	Relevant activities for VRE integration
Generators	System services and support; Harmonics; Forecasting
Transmission system operators	Manage supply side variability; System monitoring; Provide system inertia; Cooperation between neighbouring networks
Technology providers	Communication protocols; Data handling
Policy makers	Renewable energy targets; Renewable energy support policies; Mandates on interconnection, grid connection, market design and grid codes
Regulators	Definition of grid connection policies; Grid codes; Market design; Compensation schemes; Support flexibility
Energy planners	New transmission network topologies; Location specific planning; Adequacy
Certification bodies	Public engagement in power sector transformation
NGOs	Economic, environmental and social assessments of power sector transformation

Table 4. New stakeholders in the power sector transformation (Source: IRENA 2015).

New stakeholders	Relevant activities
Non-utility generators	Generation by individuals, farmers, communities, project firms, banks, industrial users
Prosumers	Self-consumption; Net-metering; Grid feed-in
Aggregators	Grid support services (through supply and demand) through energy service companies, solar leasing firms
New financers	New investment streams from development banks; municipalities, yieldcos, crowdfunding; New ownership and finance models
Technology providers	Development and implementation of smart grid technologies, storage technologies, microgrids
ICT companies	Data collection, sharing, analysis and security
Consumer service companies	Building energy management systems
Car manufacturers	Electric vehicles for VRE integration
Emergency services	Anti-islanding; Reverse power flow concerns

2.2. Plan for Neo-Carbon actor analysis

In designing actor analysis for the Neo-Carbon project, we reviewed the methodology presented in literature.

Actor analysis for Neo-Carbon project is motivated by the arisen need for "identifying & adding actors" to Neo-Carbon scenarios. Especially, this is relevant from the techno-economic point of view that often lacks thorough considerations of the actor viewpoint. Generally, actor analysis is also needed for any kind of real dissemination, e.g. for policy recommendations and/or development of an action plan (see *Table 5*). The actor analysis can reveal influences in actors' goals, strategies, and options.

Table 5. What is an action plan?

What is an action plan?
If we are to prepare an action plan in NCE project, it is seen to beneficial to describe the general characteristics required from one. According to Community Tool Box Developed by University of Kansas, an action plan may help us turn our dreams into a reality. Furthermore, it assists us to find a way to make sure our visions are made concrete and describes the way how strategies are used to meet objectives.
Importantly, there are a number of action steps. According to a website produced by University of Kansas, they should include the following information: • *What actions or changes will occur* • *Who will carry out these changes* • *By when they will take place, and for how long* • *What resources (i.e., money, staff) are needed to carry out these changes* • *Communication (who should know what?)* [2]
The content of NCE action plan is to be specified. As a multidisciplinary project, a leverage potential from various sources of information produced in the project is seen to answer the list of questions above.

2.2.1. Discussion on methods

Hermans & Thiessen (2009) present an overview of analytic characteristics of actor analysis methods, summarizing *specificity*, *logical interconnectedness* and *scope* as distinguishing factors between different methods. Altogether, they classify 18 different actor analysis methods. Logical interconnectedness of different methods varies from "checklists only" via conceptual models to mathematical models in the other end of the spectrum. In the other axis, specificity of methods varies according to abstractness of the method. An indication of scope of the method is obtained by assessing how many of the four main dimensions

[2] Source: http://ctb.ku.edu/en/table-of-contents/structure/strategic-planning/develop-action-plans/main

(networks, perceptions, values, resources) as objects of the actor analysis captured are covered by the concepts included.

Application of actor analysis for the Neo-Carbon project starts with identifying the actors. Identifying actors can be motivated by various aims. Reed et al. (2009) distinguishes the aims as follows:

- the aim of identifying actors to incorporate into the scenario per se,
- the aim of identifying actors for the purpose of developing an action plan, and
- the aim of identifying actors for participation in the process of scenario development.

Following these aims, Neo-Carbon actor analysis can be seen to have characteristics of each aim presented. The focus in this report is in the first two, as participation process is mostly included in planning of workshops done in other tasks of WP1.

Wangel (2011) presents four approaches to include actors and governance as objects of change in backcasting studies. Accordingly, there are four approaches to add actors

- Stakeholder analysis approach
- Social network approach
- Governance model approach
- Policy and change approach

The most popular methods for actor analysis are the methods that have come to be known as stakeholder analysis (Hermans & Thissen 2009). There are a variety of methods used for stakeholder analysis to identify actors to be included in the scenario (Wangel 2011). *Stakeholder* is a term used in different meanings; Bryson (2004) discusses the meaning of term *stakeholders* deeply and describes it generally as follows: *the term refers to persons, groups or organizations that must somehow be taken into account by leaders, managers and front-line staff.*

Stakeholder analysis is classified as representing *tables and matrices for stakeholder classification and participation strategies*. Stakeholder analysis is stated to *collect and structure information on stakeholders, resulting in specific participation strategies for each group* (Hermans & Thissen 2009).

Stakeholder analysis method introduced in Wangel (2011) consists of several approaches including qualitative methods such as; *structured brainstorming, focus group,* or *literature studies.* Stakeholder and social network approaches put actors in focus, whereas governance model approach as well as the policy and change approach put governance in focus.

Identifying stakeholders is usually an iterative process. This means that additional stakeholders can be added as the analysis continues. The process can build on several techniques; for example, using expert opinion, focus groups, semi-structured interviews, snow-ball sampling, or a combination of these (Reed et al. 2009). According to literature reviewed, policy processes seem to be one used application for stakeholder identification techniques. For example, TU Delft (2016) describes an analysis of New York City drinking water supply as an exemplary actor analysis approach. It has to be stressed that stakeholder in policy process is not necessarily same as actor in scenario studies.

2.2.2. Neo-Carbon framework

As discussed, description and analysis of actors involved is often lacked from studies building on methodologies based on techno-economic assessments and modelling. As these kinds of results are produced in several other parts of the Neo-Carbon project, our efforts concentrate on considering methods *how to tackle* the actor viewpoint.

In the Neo-Carbon project, many actors have been addressed and their roles and motives described in foresight-method based work with narrative WP1 storylines as a result. Interestingly, Hermans & Thissen (2009) classify narrative analysis as one actor analysis method. Therefore, not only adding actors "from the scratch" but also identification and analysis of them based on findings by other methods becomes the key issue. The process is to be tailored for Neo-Carbon project actor analysis.

Approaches for identifying and adding actors presented in Wangel (2011) do not comprise guidance on how to develop a scenario but are to be used as a complement to already existing approaches to create such – thus being a fruitable starting point for Neo-Carbon actor analysis. According to Wangel (2011) the stakeholder analysis and social network approach can be seen as bottom-up approaches; taken together actors, relations and processes constitute different models of policy-making and governance.

In the Neo-Carbon project, the work packages WP 1, WP 2, and WP 3 include building blocks and sources for information for actor analysis. That is, as their results are used as a basis for actor analysis, key stakeholders, timelines and barriers, can be identified. As the issue of moving towards 100 % RES based energy system is widely studied from different societal and techno-economic viewpoints, lucrative environment for analysis of actors is observed. Therefore, Neo-Carbon actor analysis can be described as "analysis based on analysis". *Figure 3* presents a process chart on how WP1, WP2, and WP3 results and scenarios are used to identify the key actors, timelines and barriers for Neo-Carbon Finland.

Despite borders between the nature of the results of different WPs cannot be strictly drawn, each of the sources for actor analysis (*Figure 3*) have their own profiles. Feasible timelines and scales for technologies from energy system perspective can be expected especially from WP2 results. Bottom-up technological process data as a driver for actors' future decisions can be applied from WP3 results. The strength of WP1 scenarios, especially, are capturing of societal and institutional changes, opening up new alternatives, based on the identification of megatrends, trends, and especially weak signals of change[3].

[3] More information on the scanning of megatrends, trends and weak signals in the Neo-Carbon Energy project is discussed in "Radical Transformation in a Distributed Society - Neo-Carbon Energy Scenarios 2050"
https://www.utu.fi/fi/yksikot/ffrc/tutkimus/hankkeet/Documents/NeoCarbon-WP1-1-2016.pdf

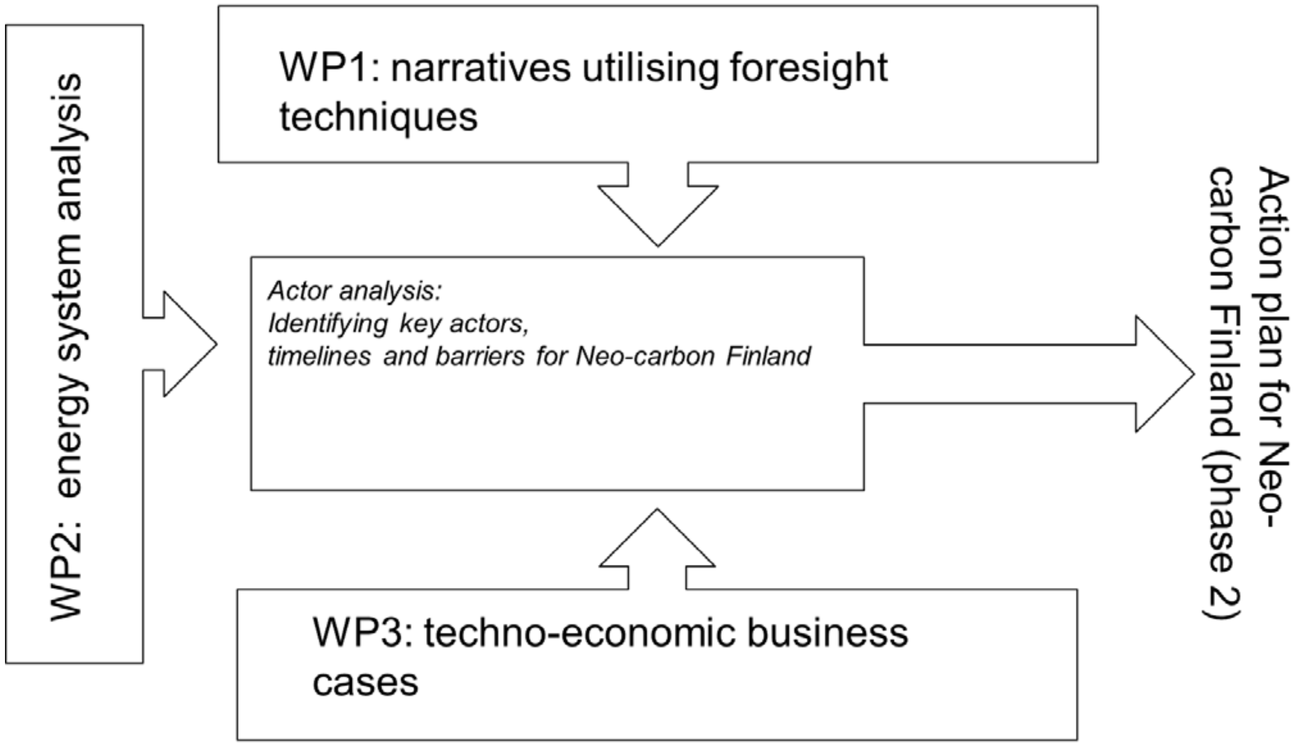


Figure 3. Building blocks of the Neo-Carbon actor analysis. WP1, WP2, and WP3 results and scenarios are used to identify the key stakeholders, timelines and barriers for Neo-Carbon Finland. Through this, a robust action plan with needed stakeholders and other actors can be developed. The approach is designed to take both technological and societal as well as policy dimensions included, providing with added value to several earlier scenario exercises.

Novelty and specialities of the Neo-Carbon actor analysis can be identified as two-fold. First, for a large part system/technologies not yet commercially exist to large scale and in the future, there may be actors & roles significantly different that those of today's. Hence, all the "textbook methods" cannot be applied as such in Neo-Carbon analysis. Second, the Neo-Carbon actor analysis does not have to be considered "from the scratch". That is, a lot of analytical considerations, model-based exercises and expertise, is or will be available as the project proceeds. This combination forms an original analytical environment compared to many earlier efforts documented in literature reviewed.

3. Actor analysis conducted in the 1st funding period

During 1st funding period (FP1), tailored actor analysis approaches for **Neo-Carbon project actor analysis** were developed and tested. The results are presented in this Chapter. The overall aim of the experiments is to define a powerful set of approaches so that actor analysis designed can and tackle the shortcomings of different methods (*Table 2*) and to develop an action plan in FP2 of the project. As there is no "textbook method" available to be directly applied in NCE analysis, work in FP1 concentrated on analysing the feasibility of different methods based on draft materials and discussions. Thus, importantly, at FP1, the goal of the work was not to deeply analyse the draft versions of source materials from the perspective of identified actors.

As a first attempt in actor analysis, the methods presented in *Table 6* for NCE actor analysis were developed and tested. The efforts completed can be broken up to serving goals of *(i) identifying* the actors, *(ii) classifying* the actors *(iii) describe* network structure between actors *(iv) describe motives*.

Table 6. Methods tested and developed in the first funding period.

Method tested	Goal	Questions	Sources	Results	Reference in this report
1. Word analysis	*Identification and classification of actors*	*Who?*	*WP1 scenarios*	*Long list of suggestions for actors and their significance*	*Section 3.1*
2. Stakeholder matrices	*Classification of actors*	*Who?*	*Wangel et al. (2011), results of word analysis of WP1 scenarios*	*Classification of identified actors based on influence and activity*	*Section 3.2*
3. Exploration of narrative storylines	*Relations between actors*	*Network structure between actors?*	*Expert judgement based on WP1 scenarios*	*Conceptual image of the network topology*	*Section 3.3*
4. Exploration of narrative storylines	*Motives of actors*	*How?*	*Expert judgement based on WP1 scenarios*	*Suggestions for different motives*	*Section 3.3*
5. Exploration of business cases	*Identification and classification of actors*	*Who?*	*WP3 business cases*	*Suggestions for key actors and their significance*	*Section 3.4*

Of variety of actor analysis methods presented in the literature (e.g. Hermans & Thissen 2009), the steps taken in phases (1, 2, 5) fall under a category stakeholder analysis**.** Thus, in the FP1 of the Neo-Carbon project, the main emphasis was put to consider methods to classify and structure information of stakeholders. Results of methods 3 and 4 describe relations between actors are based on identified and classified actors and storyline drafts of WP1 scenarios. These results can be classified as more preliminary. However, as methods 3 and 4 include discussion on characterization of networks between actors and can be categorized as a preliminary step towards social network approach. Thus, our process follows the structure by Wangel (2011) studying approaches to add actors and governance in backcasting scenarios.

As the stakeholder analysis approach was the most emphasized, we discuss the results of these methods a bit deeper in the following. Regarding the methods tested, *"Word analysis based on storylines"* builds on analysis of qualitative scenario storylines developed in Futures Clinique process by Finland Futures Research Centre FFRC (Heinonen et al. 2015)[4]. The word analysis process includes several steps depicted in *Figure 4* . Importantly, there are steps based on computer-aided search tools (Section 3.1). Thus, all their results do not necessarily automatically reflect the views of authors of the storylines. However, these intermediary results are also presented and discussed to highlight the development needs of methods identified as a result of experiments.

Figure 4. Phases of actor analysis based on word analysis of storylines. The four scenario storylines are approached through computer-aided search tools, after which the results are manually processed to better reflect the storyline authors' view of the key actors.

3.1. Mechanical word analysis based on storylines

3.1.1. First round

1st Neo-Carbon actor analysis aimed at **identifying and classifying** the actors of WP1 scenarios written on a basis of futures study methods and Futures Clinique process (Heinonen et al. 2015). Storyline drafts studied consisted of roughly 10 to 20 pages long narrative descriptions of each of the four scenarios developed in the project. To identify

[4] The transformative scenarios are elaborated and deepened throughout the scenario-building process. Therefore, in the final version of the qualitative scenarios, to be published in 2017, the actor descriptions and scenario narratives will be richer than in the initial phase.

the actors, each of the storyline drafts (with workshop and energy comments taken into account) was handled sentence by sentence. From each sentence, the actor was identified in addition to descriptive terms to answer the “Who” question corresponding to What-who table methodology described in Wangel (2011).

As a results of word analysis, a text mass expressing ”who does something” with descriptive and specifying words included was analysed and turned into *word clouds* using Wordle software[5]. In word clouds, words signalling the actors in storylines in Heinonen et al. (2015) are presented as cloud. The bigger the font, the more often an expression occurs in the text. Results of each scenario are presented in figures (*Figure 5* - *Figure 8*) and they give a rough and quick indication on key actors in each scenario

It is important to highlight that in this point, interpretation of texts was kept as minimal as possible. That is, the focus of the experiments was to study feasibility of a technical assistance tool for identifying the actors. Seeking detailed explanations of what kind of value changes would explain the observed differences in or between actor worlds was not targeted. Importantly, the first steps are based on computer-aided search tools. Thus, all their results do not necessarily reflect the views of authors of the storylines. However, it was interesting to review the results in assistance with authors of storyline drafts (Heinonen et al. 2015) to see whether the method produced results intuitively in line with the storylines. This phase revealed some guidance for development of the method and this is discussed in section 3.1.3.

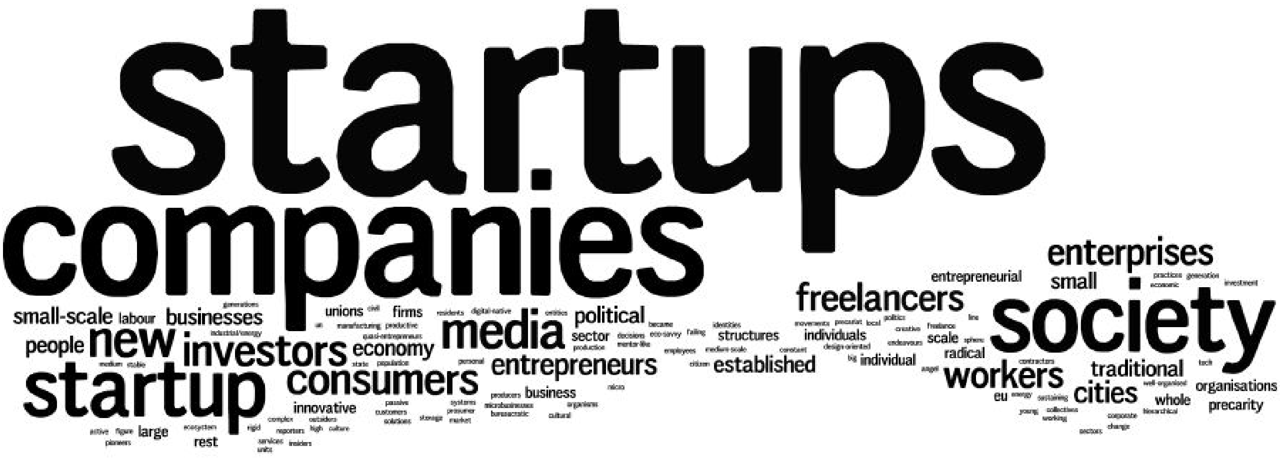


Figure 5. Word cloud based initial actor analysis on Radical Startups scenario.

5 www.wordle.net

Figure 6. Word cloud based initial actor analysis on Value-driven techemoths scenario.

Figure 7. Word cloud based initial actor analysis on Green DIY engineers scenario.

Figure 8. Word cloud based initial actor analysis on New Consciousness scenario.

Figures (*Figure 5* - *Figure 8*) present visually the word cloud based actor identification. It can be concluded that some of the actors are obvious from the scenario setting and definition. However, some interesting observations can be made. It interesting to note that relatively few "actor words" are observed in the Green DIY Engineers scenario, whereas strikingly many in the New Consciousness scenario. Another identified dimension is the variance in occurrences. This refers to if key actors can clearly be distinguished from the others or do the actors form a relatively homogenous field. According to visual impression, in *Value-driven techemoths* and *Green DIY engineers,* there are most dominantly distinguished key actors. When considering concrete action plans, for example, these features can be seen having effects.

Most obvious actor words in each of the scenarios can be visually observed in the word clouds:

- **Radical Startups:** Startup, companies
- **Value-driven techemoths**: Companies, techemoths, energy
- **Green DIY engineers:** Communities, people
- **New consciousness:** People, global, nature

3.1.2. Second round

In second round of the initial word-based actor analysis, most obvious/dominating actors were removed from the texts under review. The goal was to identify non-obvious actors from the storylines. The actors mentioned above were removed and corresponding word clouds drawn (not included in this report since the essentially same information is included in *Table 7*).

In further analysis, we also classified the actors in four groups, presented in *Table 7*. The grouping is based on sorting the words by occurrence. For example, words “startup”, “startups”, “companies” and “society” are four most frequently occurring words in the actor text mass of the *Radical startups* scenario. In combined, they occur 83 times and constitute roughly 28% of the total occurrences. “Class 2” words represent in totally 22 % of the text mass of Radical startups scenario. Since there are several words with equal frequencies, the borders cannot be strictly set e.g. to 25 %. According to similar logics, each of the scenarios has been gone through and the actors classified in four groups.

In *Table 7*, those words that can be interpreted as actors are presented in bold font, whereas the descriptive and specifying words in regular. Based on the occurrence frequencies presented in *Table 5*, a hypothesis of relative significance of actors can be straightforwardly produced. Relying on this, a suggestion of “Most important”, “Intermediately important”, “Weakly important” actors are presented. An interesting set-up for further analysis is to compare these results with those obtained by other methods such as exploration of business cases or by deeper analysis of the texts. Do the different methods suggest similar result, or can conflicts or shortcomings be revealed?

Due to visual observability, actors words mentioned only once are reported in separate table (*Table 8*). For example, in Radical startups scenario, there are 85 different words occurring only once. A look at most rarely occurring words does not reveal clear patterns. Also, a lot of supporting words are included. First impression is that many of the words seem to appear just by chance and should be cautiously interpreted. However, an identified difference between “actor landscapes” varying from Green DIY engineers with relatively few actors and New consciousness with the largest number of actors present in the field, is observable also here.

Table 7. Identified actor words classified according to their occurrence.

	Significance	Radical startups	Value-driven techemoths	Green DIY engineers	New consciousness
"Class 1"	"Most important" ~75…100% of the occurrences	**Startup(s), companies, society**	**Companies, techemoths,** energy	**Communities, people**	**People, global, nature**
"Class 2"	"Intermediately important" ~50…75	new, **media, investors, consumers, workers, enterprises, freelancers, entrepreneurs, cities**	**large, corporations, civil, people, society, google, global, states, apple,** technology, big, **citizens, sector, samsung, rich**	**diy, amateur, local, states,** self-sufficient, **engineers**	everything, **individuals, systems, millennials, citizens, society, humans, biophilia,** energy, **system,** other, connected, **communities, eu,** parts, **organisations**
"Class 3"	"Weakly important" ~25…50	**Businesses,** economy, traditional, small-scale, established, **people,** small, political, whole, large, innovative**, precarity, firms, labour, unions, business,** structures, **individuals, sector, individual, eu,** scale, **organisations,** rest, radical, entrepreneurial	**actors,** traditional, **winner, facebook,** one, **individuals, platforms,** only, few, tech**, individual, techemots, employees, company, giants**		**nations,** else, deeply, active, economy, thinking, **government,** collective, democracy, interconnected, political, post-generation**,** all, **consumers,** technology
"Class 4"	0…25 AND <=1				

Table 8. "Actor words" presented only once in the storylines analysed.

Radical startups (85 words)	big, ecosystem, complex, freelance, manufacturing, state, energy, generation, in, active, investment, personal, creative, population, medium-scale, cultural, failing, quasi-entrepreneurs, insiders, other, reporters, collectives, local, identities, prosumer, sphere, systems, civil, industrial/energy, decisions, customers, eco-savvy, rigid, bureaucratic, change, services, practices, producers, design-oriented, corporate, entities, culture, economic, constant, generations, angel, high, hierarchical, un, from, tech, citizen, sectors, endeavours, solutions, its, market, organisms, residents, outsiders, employees, politics, became, production, young, line, movements, medium, units, storage, working, sustaining, pioneers, well-organised, figure, precariat, or, passive, contractors, mentor-like, productive, micro, stable, microbusinesses, digital-native
Value-driven techemoths (87 words)	cluster, nation, 2010's, owners, competition, texas, nations, these, poor, competing, based, in, old, corporation, neutral, circular, countries, economy, hubs, innovator, cultural, at, system, value-driven, super-rich, patrons, contractor, Obama, identities, government, era, operators, systems, national, free, workers, arts, billionaires, middle, saudi-arabia, s, corporate, comers, economic, communities, duke, tesla, several, growing, industrialisation, transmission, etc, citizenry, un, ict, us, peoples, new, development, like, everyone, engineering, users, activism, eu, forerunners, especially, middle-classes, outsiders, networked, some, united, classes, policies, media, oligopoly, oil, producing, public, construction, end, city-states, or, finnish, industrial, cyber, president
Green DIY engineers (33 words)	consumed, tinkerers, community-based, prosumers, nation, isolated, youngsters, governments, individuals, investments, disconnected, society, locally, artists, national, customers, businesses, kids, energy, engineer-oriented, mind, individual, settled, countries, families, community, many, engineer, produced, producers, off-grid, cultures, self-sufficiency
New consciousness (101 words)	psychological, tendency, intertwined, focus, relationships, post-capitalism, companies, biophilic, society-wide, businesses, societies, between, large, circular, being, an, each, concepts, theory, status, systemic, independent, collectives, direct, representations, seen, local, see, identities, world, share, relationship, mix, means, business, multitude, innate, union, households, o, the, collaboration, relations, small, perfect, use, developing, major, cooperatives, only, different, international, representative, regardless, new, development, cities, everyone, multi-directionality, commitment, towards, affected, lifelike, economies, synthetic, markets, globalised, outside, parties, self-profit, vs, networked, interconnectedness, virtual, united, part, for, their, scale, inherently, life, states, fundamentally, public, themselves, working, village, human, on, responded, orientation, processes, social, socialism, seeking, cause-and-effect, productive, service, organizations, well, multitudes

3.1.3. Methodological remarks

Despite "word analysis based on storylines" can be seen as straightforward and visually attractive methodology, some methodological issues can be immediately recognized. These are related to expression style and "linguistic" phenomena observed through testing the method by using Heinonen et al. (2015) as a source material. That is, the following factors were identified to potentially having an impact on result of the analysis

- Plurals, synonyms, common words
- Negative vs positive expressions
- Expressions consisting of several words
- Compact vs extensive expression style
- How to include descriptive words in "actor words"
- Fundamental definition of an actor
- Context in which the actor is mentioned

The first results present a rough picture on the key actors based on analysis of the narrative storylines. That is, no emphasis have been put on analysing the synonyms, plurals etc. but the methodology aimed to be based on "mechanical" or "automated" process as much as possible. As its strength, it gives a small role for subjective interpretation of the individual researcher conducting the analysis.

Some subjective choices had to be made, however. For example, analysing the following piece of text from the studied Radical Startups scenario narrative:

> *"Instead of a global scale, most startups operate locally and regionally. They provide for local needs and solve environmental problems on-site."*

In the first sentence, "startups" is an obvious actor. In the second sentence, it is replaced by an expression "they". To be precise, a correct approach might be counting "startups" as an actor in the second sentence, too, resulting in totally two occurrences in this piece of text. In the first analysis, no such a far-reaching effort was made, however. We have interpreted words "locally" and "regionally" as describing words. This represents, however, a choice, where also other approaches could be justified.

Another example of methodological shortcoming in the first tests implemented is observed words consisting of several words. Splitting "Labour Union" in parts "Labour" and "Union" blurs the exact meaning of the actor mentioned. On the other hand, if there would be different "Unions" often mentioned, separating the expressions consisting of multiple words would mask the significance of "Unions" as a group. Whatever the choice is taken, the issue could be easily tackled with technical means of the word analysis software, if considered necessary.

Further discussion is related to fundamental definition of "actor word". Review of the results revealed a need for candidates for actors based to be filtered to in light of the problem studied. For example, is it relevant to question whether we can accept "society" as an actor. Even though it is "doer" of the action in grammatical sense and meets with the definition of how the texts were handled, it is relevant to question "who should you call" if you'd like to influence "society" as it includes "us all". Thus, it might be justified to add some kind of checklist to filter the candidate words.

Example of context is provided by the expression of Green DIY scenarios: ”states have more or less withered away”. Thus, again, state is the doer but the context defends its removal from the key actors. To prevent this kind of phenomenon, one might deeper go through the expressions in the raw texts and remove the actor candidate word if its low significance is clearly suggested by the expression. Also, the added value of words such as “in“, “from“, etc. is practically non-existent so they could be directly removed from the text mass studied.

It remains an open question if any added value in respect of goals of the project could be produced by deepening the analysis by tackling the methodological issues identified above. Initial hypothesis is that ”big picture” would probably appear roughly the same even though some specification in the word analysis guidelines could be defined. Guidelines as unambiguous as possible in word analysis, however, are recognized as a desired characteristic for subsequent development of this type of analysis.

Once having a preliminary view of the actors and their significance identified, a focus is next turned in stakeholders: as a reminder, *the term refers to persons, groups or organizations that must somehow be taken into account by leaders, managers and front-line staff* (Bryson 2004). Having a target defined as radical as turning the world running with 100 % RES based energy system, very large number of different actor types can be argued to be classified as stakeholders.

3.2. Stakeholder matrices

As a part of stakeholder analysis, we have drafted *stakeholder matrices* based on Wangel (2011) for each scenario. Tables (*Table 9* - *Table 12*) present the results of this process as a first attempt. It is of importance to highlight that there are four different *transformative* scenarios developed in the Neo-Carbon project, each of which have differing actor landscape. The common target of the scenarios is an energy system towards 100 % RES highly based on solar, wind, and power-to-gas storages.

Identified stakeholders are placed on tables based on a model by Wangel (2011) who studied a scenario study of green mobility in Bromma, Stockholm, Sweden as an example. The stakeholder matrix framework distinguishes between five different groups of stakeholders based on when in the development process each group is most active, and which kind of influence it can exercise.

Stakeholder matrices present a one-step more sophisticated analysis and research work than more mechanical storyline-based words analysis (section 3.1). That is, in this phase, some manual consideration was applied. However, it is clear that many of the choices are arguable and therefore the experiment is to be considered demonstrative. Here, based on word analysis, the most important actors based on *Table 7* were assessed and placed on tables (*Table 9* - *Table 12*) to distinguish their influence in a timeline towards 2050. Years 2020, 2030, and 2050 are chosen as demonstrative as these years are typically present in European Union and national energy and climate policy planning horizons. Also, at this point, some processing was made for the word mass. Words considered irrelevant were removed and some synonyms were combined as single actor words.

Following a model in Wangel (2011), *Table 9* introduces a suggested draft stakeholder matrix for Radical startups scenario based on word analysis. Two most important categories based on Table 5 were considered in the experiment. That is, if we aim technological solutions towards 100 % RES based energy system in 2050, correspondingly, **startups, companies, investors, workers, cities**, and **entrepreneurs** are suggested as stakeholder groups with direct and formal power to influence in planning phase[6]. Startups, companies and entrepreneurs fall in a category of business actors. Reflecting to scenario description, these actors can be seen as potentially having a role in the field of small-scale and innovative energy solutions, for example. **Media**, **freelancers** and **consumers** are categorised as stakeholders with no direct formal power to influence. The media - traditional and social - can influence in public opinion and therefore having an impact on social decision-making or penetration of innovations, for example.

As going further in implementation phase ("Putting the plans in practice"), freelancers and consumers can be seen having a direct but varying influence. That is, having the products needed commercially ready, at least a part of investment decisions will fall over single consumers and making them as a direct influencers. Investors and cities, correspondingly, are suggested to not having a direct influence in this phase.

Table 9. A draft stakeholder matrix, Radical startups scenario.

"Neo-Carbon" world: Stakeholder matrix/Radical startups	
Planning phase ("2020") **(Production of and agreements in e.g. plans, programs, or contracts)**	
Direct and formal power to influence	Startups, companies, investors, workers, cities, entrepreneurs
No direct formal power to influence	Media, freelancers, consumers
Implementation phase ("2030") **(Putting the plans into practice)**	
Direct but varying influence	Startups, companies, workers, cities, entrepreneurs, freelancers, consumers, investors
Expert advice	Investors, cities, media
End-use phase ("2050") **(Using and managing the objects of change, or reluctance to them)**	
End-users and managers, direct and indirect influence	Startups, companies, entrepreneurs, freelancers, consumers

Value-driven techemoths scenario considers **large technology companies** "**Techemoths**" as main drivers of the development as Google, Facebook, Apple and Samsung are mentioned as exemplary of this type of companies in the text. It seems natural to assess that strategies of these companies strongly outline the development towards Neo-Carbonized world in the scenario. Also, in this context it seems natural to discuss if the role of **citizens**,

[6] "Society" removed based on discussion in chapter 3.1.3

people, traditional **states** and societal structures is not as strong, as suggested in *Table 10*. However, civil society's "innovator fringes" are suggested in the development described in the text. Interestingly, the word **"rich"**, referring to wealthy people, is mentioned in the text so strongly that the results of the word analysis suggests it to be among the second strongest group. According to the text analysed (Heinonen et al. 2015), this indeed refers to inequalities suggested to become more visible in the scenario, as "*Because their profits are dependent on disruptive technologies, the rich have become a technologically and culturally progressive force in society"*. One can then assess the rich people having a direct influence, demonstrated through "rebirth of the industrialisation era patrons".

Table 10. A draft stakeholder matrix, Value-driven techemoths scenario

"Neo-Carbon" world: Stakeholder matrix, value-driven techemoths	
Planning phase ("2020") **(Production of and agreements in e.g. plans, programs, or contracts)**	
Direct and formal power to influence	Large technology companies, techemoths, "global economy"
No direct formal power to influence	citizens, people, society, states
Implementation phase ("2030") **(Putting the plans into practice)**	
Direct but varying influence	Large technology companies, techemoths, society, "global economy", citizens, rich [people]
Expert advice	society, states
End-use phase ("2050") **(Using and managing the objects of change, or reluctance to them)**	
End-users and managers, direct and indirect influence	Large technology companies, techemoths, rich [people]

Actor landscape of Green DIY engineers scenario with relatively few actors groups (but potentially many individuals) is drafted in stakeholder matrix of *Table 11*. As, according to storyline, governance is highly organised on local basis, it can be expected that **local communities** would play a big role in "planning phase"[7]. As DIY solutions are suggested to play a big role different to Radical Startups scenario, it can be foreseen that **people** and "**DIY engineers**" have more direct influence in realisation and actually putting the plans in practice of this scenario, taking a form in developing technological solutions spreading in local communities.

[7] "states" removed based on discussion in chapter 3.1.3

Table 11. A draft on stakeholder matrix, Green DIY Engineers scenario.

"Neo-Carbon" world: Stakeholder matrix/GreenDIY engineers	
Planning phase ("2020") **(Production of and agreements in e.g. plans, programs, or contracts)**	
Direct and formal power to influence	local communities
No direct formal power to influence	people, "diy engineers"
Implementation phase ("2030") (Putting the plans into practice)	
Direct but varying influence	local communities, "diy engineers" people
Expert advice	local communities, "diy engineers"
End-use phase ("2050") **(Using and managing the objects of change, or reluctance to them)**	
End-users and managers, direct and indirect influence	local communities, people, "diy engineers"

Table 12 suggests a stakeholder matrix for the New consciousness scenario. Accordingly, the role of international organisations and global systems is evident in all the phases, although they do not necessarily directly control the objects of change such as energy production facilities and transmission systems.

Table 12. A draft stakeholder matrix, New consciousness scenario.

"Neo-Carbon" world: Stakeholder matrix/New consciousness	
Planning phase ("2020") **(Production of and agreements in e.g. plans, programs, or contracts**)	
Direct and formal power to influence	International collaboration and global systems (enabled e.g. by EU, international organisations)
No direct formal power to influence	People, global systems, society, humans, communities
Implementation phase ("2030"?) (Putting the plans into practice)	
Direct but varying influence	global systems, millennials, society, humans, biophilia, communities
Expert advice	EU, organisations
End-use phase ("2050") **(Using and managing the objects of change, or reluctance to them**)	
End-users and managers, direct and indirect influence	People, global systems, millennials, society, humans, biophilia, communities, EU, organisation

As general observation, the actors identified here (*Table 9* - *Table 12*) are not very specified, as they concern large, and even global scales. Also, there seems to be more general societal scope compared to actors identified in IRENA (2015), presenting actors in more specified technological electricity system in focus. Thus, the scale of actors identified based on Neo-Carbon storylines is much larger than practical and local policy related problem as e.g. in TU Delft (2016) or Wangel (2011). In examples presented in these studies, actors as specified as *Delaware County Dept. of Planning and Econ Development*, *Stockholm Public Transport (SL),* for example, are identified*.*

Stakeholder matrices (*Table 9* - *Table 12*) can be immediately seen to signal differences between the scenarios. Generally, in *Value-driven techemoths* and *Radical startups* scenarios, the actors with power to influence seem to fall under categories of companies, businesses and entrepreneurs. The consequence of this for action plans, for example, can be seen as economic as major driver to influence these actors

In *Green DIY engineers* scenario, relatively few actors types are identified in comparison to others. Considering the nature of the scenario (see Heinonen et al. 2015), it is natural that as being driven by self-made and communal efforts, this reflects also to the results of initial stakeholder analysis. Thus, *local communities, states, people,* and *"diy engineers"* are identified as key influencers in the scenario.

In *New consciousness* scenario, global systems face a radical transformation and the word analysis suggests very diversified actor field. Thus, key single actors running the transformation are more difficult to identify on a basis of stakeholder matrix. In a light of description of the scenarios (Heinonen et al. 2015), this observations seems feasible. That is, according to storylines in New consciousness scenario, deep ecological values have spread to all the sectors of societies. Considering actors it is natural to set high expectations on global co-operation in the scenario, reflecting to *global systems, eu, and organisations* positioning high in the stakeholder analysis. Interesting actor group presented in New consciousness scenario is *millennials*, a demographic cohort whose birth years roughly range from early 1980s to somewhere around 2000s. To demonstrate dynamics of the development, this actor group can take a stronger role in the future as suggested in Table 10.

As robust action plans, planned to be drafted in further phases of the Neo-Carbon project, are worked on, the above observations on actors based on societal transformative scenarios might prove valuable.

3.3. Initial characterization of NCE scenarios

Based on actor analysis tests conducted based on (Heinonen, different types of actor networks were characterized from NCE scenarios.

Table 13. Initial characterization of actor networks for actor-based scenarios.

	Radical startups	Value-driven techemoths	Green DIY engineers	New consciousness
Who	”Startups” Small-scale actors	”Large companies”	”DIY engineers”, People, communities, Local governance	”All”, Global networks
How	Value-oriented	Market-oriented	Localised, pragmatic	Value-oriented, international collaboration, interconnectedness
Number of actor types based on word analysis	”Medium”	”Medium”	”Small”	”Large”
Number of actors (decision-making entities) based on storylines	”Many”	”Few”	”Many”	”Many”
Network characterization	Dispersed, Company-company	Sparse, Company-company	Dispersed, localised	Deeply intertwined, wide

Table 13 characterizes a suggestion of summary of actors involved and in scenarios described in Heinonen et al. (2015). In addition to word analysis, the ideas presented in *Table 13* are largely based on expert judgement by the authors based on source material from Heinonen et al. (2015). It forms elementary building blocks for quantitative modelling. The following qualities are identified:

Key actors (“who”) are identified in *Table 13* through analysis of storylines building on foresight methodologies (see Chapter 3). Startup companies and other small-scale actors dominate in “Radical Startups”, whereas in “Value-driven techemoths”, large, even giant companies, are considered the key actors. “Green DIY engineers” scenario has “DIY engineers“ identified as an obvious key actor driving the development. As “People” and “Communities” were found also highly present in the storylines, local governance is suggested to play a key role. According to storyline analysis, New Consciousness was assessed as the most diversified scenario in respect of actor types. That is, the actions taken were seen to spread globally all over the societies involving a large number of actor types.

“How” reflects on axis on values presented in Heinonen et al (2015). There, deep ecological values are attached in “New Consciousness” and “Radical Startups” scenarios, whereas pragmatic ecology, markets and practical mindset are present in Value-driven techemoths and Green DIY engineers scenarios. According to Hermans & Thiessen (2009) values “describe the internal motivations of actors”. This characteristic may have significance in defining the objective functions for the quantitative models, for example.

Number of actor types refers to identified groups. According to storyline analysis, New Consciousness was assessed as the most diversified scenario in respect of actor types. That is, the actions taken were seen to spread globally all over the societies involving a large number of actor types.

Number of actors (decision-making entities) refers to numbers of variations among the agents belonging to group. For example, one actor type “Consumers” may involve even millions of actors to be included in the models, each potentially having a different profile on behaviour.

Network characterization aims at demonstrating the links with the actors in rough scale. According to storylines analysed, most intertwined and wide network are suggested for New Consciousness scenario. This is reasoned by both high number of actor types and decision-making entities. Green DIY Engineers, scenario, on the contrary, the operations highly build on local actions, suggesting dispersed and localised network topology. Activity between companies can be seen especially emphasized in “Radical startups” and “Value-driven techemoths” scenarios.

Earlier in Chapter 3 it was observed that the actors identified based on societal scenarios storylines described the actor landscape somewhat more generally compared to more specifically electricity/energy oriented presentation in IRENA (2015). As a consequence, depending on the nature of quantitative case approached, further work on more energy specific NCE actor analysis might prove helpful. In the next phases of the project, further collaboration with WP1 market design studies, WP 3 business cases or external actors actually working in the field might provide well-founded approaches for this.

3.4. Business case based actor analysis

3.4.1. First round

"Exploration of business cases of WP3" is based on expertise developed in business case analysis, accumulated through detailed description of process concepts involving VTT and LUT research. The expectation here is that information on key actors can be produced through focused discussions and interviews with researchers having a deep hands-on experience on techno-economic prerequisites of the Neo-Carbon concepts.

For further steps in actor analysis, collaboration was made with WP3 research to include and utilise results from concrete business cases. The aim was to identify the key actors of Neo-Carbon energy system based on WP3 expertise and results on different Neo-Carbon concept profitability.

First, this was approached by developing a template tailored to Neo-Carbon project (*Table 14*) to be filled. It was planned that based on business case studies, appropriate Neo-Carbon technologies and business cases that best fit for societal scenarios, are chosen. In this way, an effort to answering the question "*who could make the change*" is made based on concrete business cases developed. It is targeted that actor analyses relying on high-level narratives are complemented with business case analysis and that technological and economic issues could add a valuable practical viewpoint to societal and energy system scenarios.

In exploring the business cases, questions to be answered in actor analysis included

- *What types of actors involved (for example, to increase the technological performance, needed investors, i.e. public/private, etc.)?*
- *What exemplary WP3 case would fit in each WP1 scenario (could e.g. households -> DIY work? Radical Startups –> container? Techemoths -> larger system?)*

A template for exploring the business cases was developed (*Table 14*). Filling was further facilitated by the following question:

Based on business case studies and profitability analysis, what actors and changes could be needed to enable "Neo-Carbon style" energy system transformation? Are there any barriers? Use current model as a reference. Please fill in the table below based on your key observations.

Table 14. Template for business case based Neo-Carbon actor analysis.

Case example: household/industrial/community (waste water) (fill 1 table/case)					
Relevant for scenario:					
Types of actors, e.g.	Actor (who?)	Change needed	Barriers	Timeline (<5 years, ~10 years, 20-30 years)	Importance (low, medium, high)
Research					
Authorities (regional, national)					
Organisations, NGOs					
Businesses					
Utilities					
Consumers					

3.4.2. Second round

As filling the tables (Table 11) was tested, further discussions with Neo-Carbon business case researchers suggested the initial definition of the task being somewhat too vaguely determined. This shortcoming was tackled by identifying a few archetypes of key actors in collaboration with the researchers. The actor network in each of the identified archetypes was explored by asking the researchers to fill the updated prepared templates; that is, five different templates were developed and additional instructions given.

An approach was further specified and introduced as "bottom-up" to illustrate the nature of the effort. This referred to starting from business/"micro" level in contrast to societal "top-down" approach by UTU/FFRC/WP1 building on megatrends and global phenomena. Actor was specified as organisation, business, authority, or any decision-making agent relevant for Neo-Carbon energy system breakthrough. It was emphasized that the goal is not to list all the actors in society but to identify the relevant ones

Following" imperative approach" introduced in TU Delft (2016), the following question was added to instructions to facilitate the respondents to identify the actors.

'Who has an interest in or feel the consequences of the issues around the solutions that are being considered?'

On the basis of discussions and materials delivered, the following "actor archetypes" were identified with different strategies on the energy system transition towards Neo-Carbon type.

- Big, established companies actively keeping the same market in an environment of holistic system change (e.g. moving away from fossil fuels).
- Startups, "better product". Young, agile companies. Example: renewable wind and solar fields and associated P2G tech.
- Industrial passive adapters – the primary product being elsewhere. This term refers to industrial players whose primary business is not directly related to NCE technologies. Thus, this type of player is not actively promoting or developing the technologies. But it is keen to take it in use provided that it is intriguing from an economic perspective.
- Do-It-Yourself. For example, small-scale inventors with a passion on technology, demonstrations, and new gadgets. Single-house owners in central role; the role of slow adapters/ forerunners.

The experts were requested to list the actor network starting from an exemplary business or another actor type in identified archetype; More specifically, the researchers were challenged to think about what actors could be needed to enable "Neo-Carbon style" energy system transformation in the specified case. The key actors (types) in this set-up were requested to be identified. The following supporting questions were included in the material delivered to business case researchers.

- *Think of actor network. Which actors are needed in supporting role? Are there any changes needed?*
- *Discuss barriers and drivers: is all the needed technology ready? Are support mechanisms in central role? Could funding be an issue? The role of slow adapters/ forerunners?*

In the latest discussions with WP3 researchers it was concluded that the updated templates per se provide a good starting point for deeper actor analysis. The actor analysis related work done building on word analysis, on the other hand, concluded inclusion of specifically energy related issues being one criterion that could be deepened on in the future. WP3 builds part of its Funding Period 2 research on assumption of the main players being new, large investors outside the utilities industry. The players' drivers of actions will be studied in WP3 during Funding Period 2 through interviews with different actors (equipment manufacturers, energy investors, incumbent utilities, industry partners), among other methods. The results will provide with better possibilities to make evidence-based conclusions on the actors. Thus, it was concluded that the WP1-WP3 collaboration will be continued and deeper actor knowledge will be produced in Phase II of the Neo-Carbon project taking into account the preliminary results.

4. Feasibility of quantitative approaches for NCE actor analysis

After exploring and testing methods to identify and add actors in the NCE framework (Chapter 3), agent-based modelling was identified as intriguing approach to explore the actor analysis quantitatively. Ideally, quantitative computer-aided modelling calculations could be used to analyse NCE related questions including actors' perspective.

As a first action, the literature and methodology were reviewed to explore the feasibility of agent-based modeling in context of future "Neo-Carbonized" energy system. Findings of the agent-based analysis considerations are reported in this Chapter. This part of the work mostly relied on review of external studies whose subject is close to NCE. The aim is to map options most suitable applications for NCE. *Table 15* summarizes the content of this chapter.

Table 15. Quantitative methods reviewed.

Method tested	Goal	Questions	Sources	Results	Reference in this report
-	*Feasibility of quantitative agent-based modelling*	*How could the actors' interaction be modeled?*	*External literature*	*NCE related cases reviewed*	*Sections 4.1-4.4*

4.1. Questions and approaches explored for NCE

Quantitative modelling approach in Neo-Carbon actor analysis framework – as in any modelling effort – has to consider the nature of the problem to be modelled. Depending on planned use of the model, different approaches are powerful. It is to be defined if the goal in NCE is to e.g. test hypothesis or use the model for predictions, as the model purpose has its own demands on the approach.

Based on the goals of the NCE project, suitable possibilities for application of agent based modeling were scanned. The first possibility identified related to actor analysis in NCE context was adoption of technology including a large number of decision-makers. This approach has NCE related applications e.g. in studying vehicle and distributed energy investments, such as residential PV systems, in large populations.

In agent-based modelling context, behaviour of individual agents and social interaction have been captured by quantitative approaches in the literature. We review these issues theoretically and analyse agent-based method in a case of penetration of small-scale PV panes in districts with a high number of stakeholders and decision-makers, a topic closely linked to the scope of the Neo-Carbon project. In this example, different technology diffusion models were applied. As social interactions and agents were found central pieces of actor analysis approaches considered for NCE in qualitative methods reviewed, the analysis supports studying the feasibility and potential of quantitative actor analysis approaches.

4.2. Modelling new technology adoption

Innovation diffusion research seeks to understand how ideas, products and practices spread throughout a society over time (Rogers 1962). By diffusion is meant processes such as contagion, mimicry, social learning etc. Innovation diffusion is a dynamic process dominated by social influences. Innovation does not lend itself to description in terms of a theory of equilibrium (Schumpeter 1928).

4.2.1. Top-down approach

Mathematical modelling of innovation diffusion has attracted academic interest since 1960s following diffusion of innovations theory by Rogers (1962)

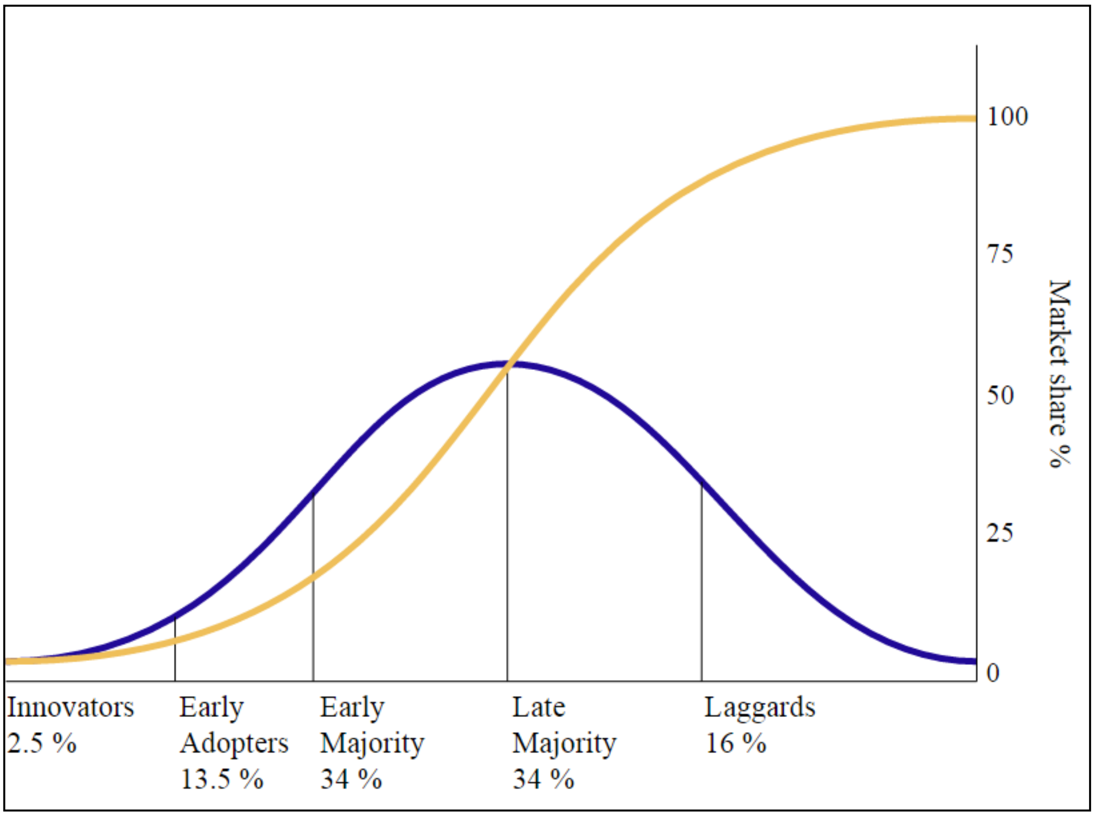


Figure 9. Diffusion of innovations according to Rogers. With successive groups of consumers adopting the new technology (shown in blue), its market share (yellow) will eventually reach the saturation level. In mathematics, the yellow curve is known as the logistic function. The curve is broken into sections of adopters. Source: Wikimedia Commons

It explains how an idea or product gains momentum and diffuses, or spreads, over time through a specific population or social system. The key to adoption is that the person must perceive the idea, behavior, or product as new or innovative. There are five established adopter categories, and while the majority of the general population tends to fall in the middle categories, it is still necessary to understand the characteristics of the target population. When promoting an innovation, there are different strategies used to appeal to the different adopter categories.

- Innovators - These are people who want to be the first to try the innovation.
- Early Adopters - These are people who represent opinion leaders.
- Early Majority - These people are rarely leaders, but they do adopt new ideas before the average person.
- Late Majority - These people are skeptical of change, and will only adopt an innovation after it has been tried by the majority.
- Laggards - These people are bound by tradition and very conservative.

In addition to academic interest also management practitioners showed considerable interest in diffusion models because managers can benefit from tools that help them estimate market responses to new products, provide model-based decision support and allow them to assess new product introduction strategies (Kiesling et al. 2012).

The most influential modelling work has been that of Bass (1969). Bass characterizes the diffusion of an innovation as a contagious process that is initiated by mass communication and propelled by word-of-mouth.

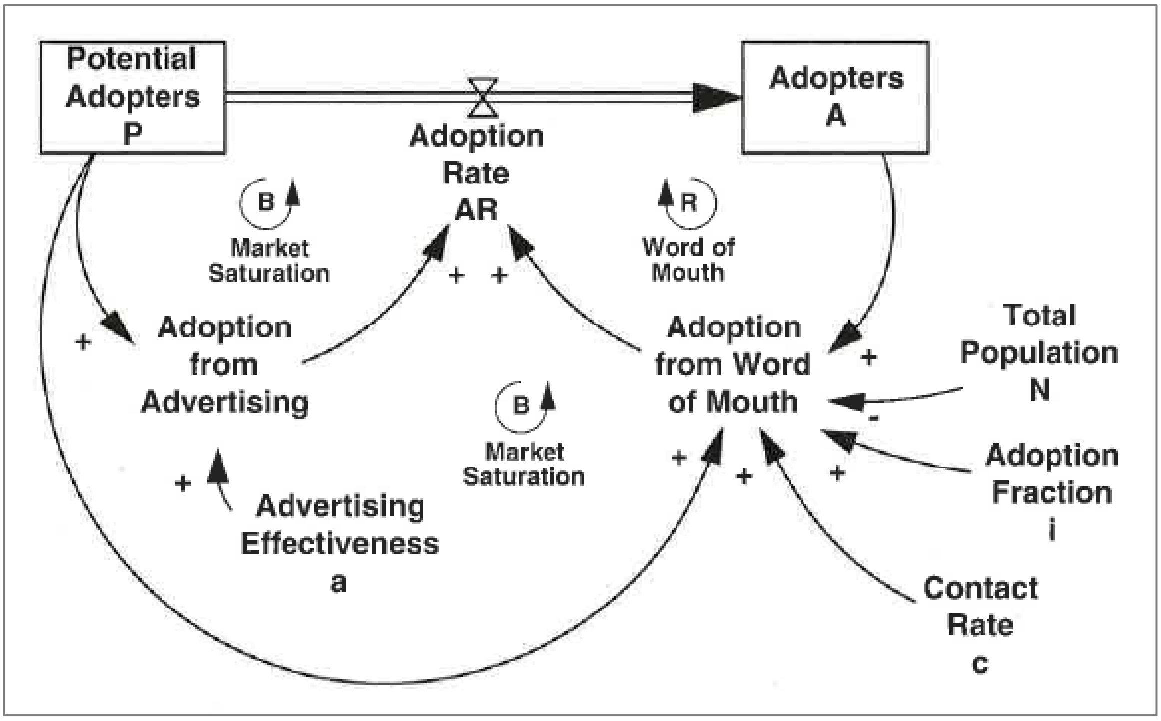


Figure 10. The Bass diffusion model (Sterman 2000)

The dynamics of the model can be described by a differential equation as follows:

$$\frac{dA}{dt} = aP + r \cdot cP \cdot \left[\frac{A}{N}\right]$$

The total adoption rate is a sum of the two adoption drivers. Bass assumed that the probability that a potential adopter will adopt as the result of the exposure to a given amount of advertising. The volume of the advertising and other external influence is assumed to stay constant. People in the relevant community come into contact at a rate of *c* per person per day. The total rate at which contacts are generated by the potential adopter pool is then *cP*. The proportion of adopters in the total population, *A/N*, gives the probability that any of these contacts is with an adopter who can provide word of mouth about the innovation. The adoption fraction, *r*, is the probability of adoption given a contact with an adopter. The behaviour of the model is the classic S-shaped growth of the logistic curve, *Figure 9*.

One of the advantages of this modelling paradigm is that it provides a parsimonious and analytically tractable way to look at the whole market and interpret its behaviour. A related advantage is that these models make use of market level data to forecast sales, which is typically more readily available than individual-level data. Based on this original formulation, a number of efforts have been made to extend and refine the Bass framework to reflect the complexity of new product growth.

However, several limitations of aggregate-level models in general and the Bass model in particular, have been identified in the literature. Of special interest here are the following (more of this in Kiesling et al. 2012).

Population heterogeneity. The mathematical form of the Bass model is based on the assumption that the potential adopter population is homogeneous. However, potential adopters are typically heterogeneous in economic factors such as income, individual preferences, the information they have etc., and consequently in their propensity to adopt. To consider heterogeneity in traditional diffusion models, compartmental approaches were developed that aggregate the population into a relatively small number of states such as unaware, aware, in the market, adopters etc.

Social processes. The simple structure of aggregate models does not make it possible to distinguish effects of different social processes on diffusion. For example, the internal influence parameter *p* is often interpreted as word-of-mouth (hereafter WoM). However, it can also capture imitation effects such as social learning, social pressures, or network effects. Furthermore, Bass-type models make very specific assumptions about the structure of social interactions. The formulation implies a fully-connected social network in which everyone in the target population is directly connected to everyone else, and can potentially influence all others. It also presumes that the influence of adopters on non-adopters is a linear function of the number of adopters throughout the diffusion periods. Because of these simplifying assumptions, the coefficient of imitation cannot be expected to directly reflect the underlying social mechanisms that shape diffusion processes.

4.2.2. Bottom-up approach

By putting the individual agent in focus gives a possibility to take into account both the heterogeneity of the population and the interactions that exert social influence, and thereby allow them to take the structure of social interactions into account.

Key elements of this agent-based based bottom-up approach for innovation diffusion are presented in *Figure 11*.

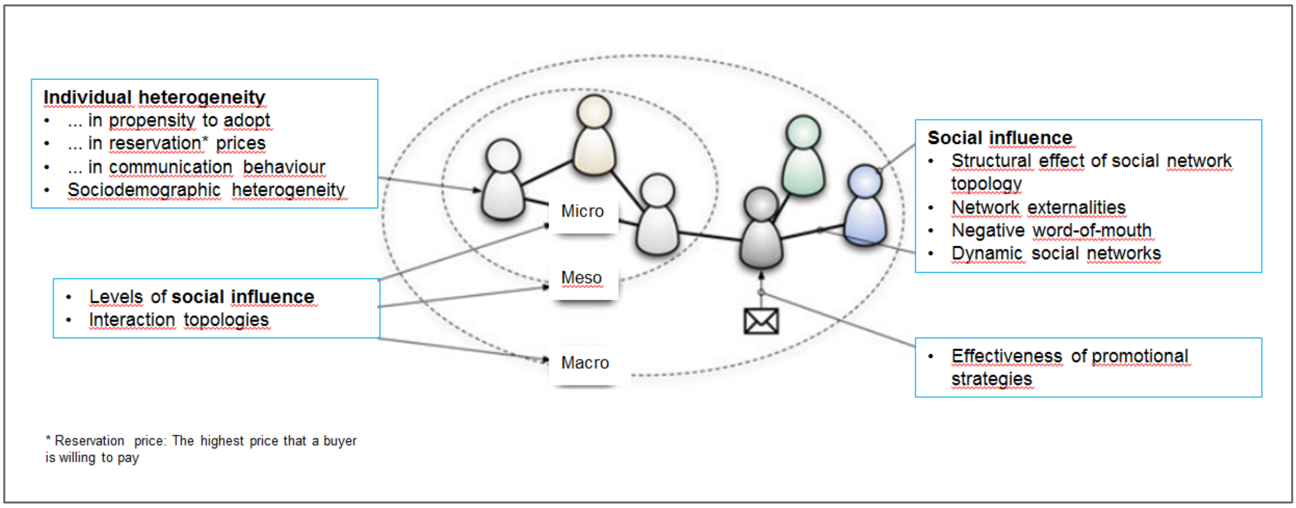


Figure 11. Key elements of an agent-based innovation diffusion model (modified by the author from Kiesling et al. 2012).

There is no universally agreed definition on what constitutes an agent. However, for practical purposes it can be described as an autonomous decision-making entity that interacts with other agents and the environment by applying a set of behavioral rules. Agent-based modelling (ABM) is a bottom-up, disaggregate approach and due to this it has all the capacity to account for heterogeneity and social structure. ABMs differ from the top-down or aggregated models in that the macro-scale phenomena are generated through applying the micro-level behavioral rules and interactions. There are no separate formulas or rules for the whole system level.

The bottom-up modelling approach can easily incorporate micro-level drivers of adoption, bounded rationality, imperfect information, and individuals' heterogeneity in terms of attributes, behaviour, and linkages in the social network. ABMs of innovation diffusion are therefore more behaviourally based than aggregate models. In the spirit of modern complexity science, these models have the potential to explain complex non-linear diffusion patterns observed in the real world as the result of relatively simple local micro-level interactions.

Individual agents

The two main issues in describing an individual agent are models of consumer adoption process and the influence of consumer heterogeneity.

Heterogeneity

A key strength of ABMs is that they overcome the homogeneity assumption of the traditional aggregate diffusion models. The propensity to adopt is the most common way to incorporate consumer heterogeneity in ABMs. It is carried out by drawing threshold values from a distribution and using them in the agents' decision rules. Structurally similar but conceptually different approach is to model heterogeneity in terms of varying individual reservation prices. For example, agents adopt when any of their neighbour has adopted and the price falls below their individual reservation price drawn from a distribution of plausible prices. Heterogeneity can also be applied in communication behaviour.

Individual contact rate is a concept that characterizes agents' features and affects the diffusion of new products.

Decision rules

The structure of a typical decision rule is such that the value of a decision variable or an index is compared to a static threshold value. Adoption takes place if the index is either lower or higher than the threshold value. An example of a simple rule is to adopt as soon as at least one of an agent's acquaintances or a certain share of them has adopted. This rule can be interpreted as contagious spread of information about the innovation. Another example of a decision variable is the utility the adoption will provide and that utility is compared with the threshold value.

A number of innovation diffusion models have adopted ideas from opinion dynamics literature. It states that consumers develop preferences in a collective process of opinion formation. Opinions are updated by means of Bayesian inference based on observed adoption behavior of neighboring agents.

Social psychology approaches apply psychological rules in describing the agents. Ajzen's theory of planned behavior is commonly used theoretical foundation in diffusion models. It postulates that the behavior of an individual can be predicted by her attitude, perceived behavioral control and intention. An example of using this theory is shown in the end of this chapter.

Social interaction

Levels of social influence

Agent-based models offer the opportunity to explicitly model the interactions that exert social influence. Social influence is a concept that can operate on multiple levels. *Figure 11* distinguishes three levels of interaction: micro, meso and macro.

By micro-level influence it is meant pairwise communication links. Word-of-Mouth (WoM) is the most relevant form of micro-level social influence. Evidence suggests that negative WoM has a much stronger effect that positive WoM (Richins1983).

Meso-level social influence stems from an agent's immediate social environment, i.e., neighbourhood. Here the social meaning can be more important than the intrinsic value of a product. Meso-level is associated with concepts such as group conformism, social comparison, herding behaviour, local network externalities.

Macro-level social influence describes interactions at the societal level. An example of this is the influence of the aggregate network-level opinion or macroeconomic feedback such as learning effects based on cumulative sales.

Network issues

Awareness, information, and opinions about an innovation are spread through the links of consumers' social network. The structure of this network and its effect on the innovation diffusion is one of the most researched topics in agent-based diffusion literature (Kiesling et al. 2012). Small-world, regular network, random network, scale-free network are names of typical network topologies used in ABMs. As an example, Bohlmann et al. (2010) conclude that network topologies are a key factor in determining an innovation diffusion process and its pattern and that in particular highly clustered networks can have substantially different diffusion patterns than more randomly connected networks.

Network externality is also one subject of simulation studies. Network externality means the situation in which the usefulness of a product increases with the number of consumers using it. Network externalities consistently have a "chilling" effect on the profitability of new products (Kiesling et al. 2012). The destructive potential of negative WoM has long been acknowledged, but its important role in innovation diffusion processes has been neglected in traditional models. Results indicate (Moldovan 2004) that resistance leaders will reduce sales significantly, as a function of both their relative number and the strength of their social influence.

4.3. An example of applying agent-based approach

Recent studies on residential solar photovoltaic (Rai and Robinson 2015, Robinson and Rai 2015) present a theoretically-based and empirically-driven agent-based model of technology adoption. Using household-level resolution for demographic, attitudinal, social network, and environmental variables, the integrated ABM framework is developed and applied to real-world data covering 2004 - 2013 for a residential solar photovoltaic (PV) program at a city scale.

The modelling goal is to build a household-level agent-based model that is able to generate empirically observed temporal and spatial patterns of the adoption of residential solar at the city scale. The household-level database is a combination of granular socio-economic demographics and environmental data for every household in the study area as well as detailed time-series rebate program and survey data for the solar adopters. This combination of carefully overlaid data-streams is critical in enabling the modelling of the economic, attitudinal, and social network attributes.

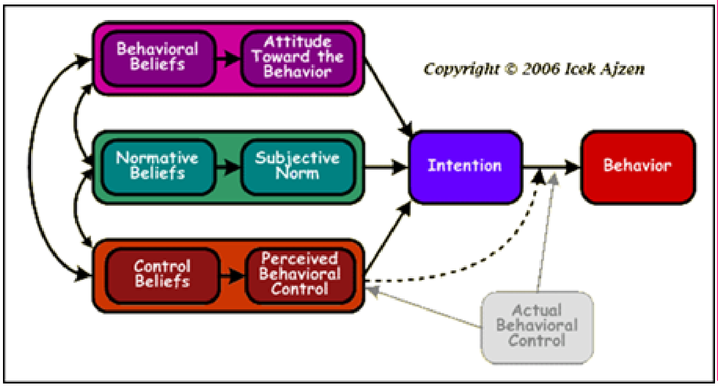
4.3.1. Theoretical background

The formulation of the behavioural model is based on the Theory of Planned Behavior (TPB) - a widely applied behavioural model in psychology (Ajzen 1991). TPB states that human behaviour is the result of the intention to perform the behaviour. The intention itself is driven by the individual's attitude toward the behaviour, subjective norms[8]and perceived behavioural control (pbc), i.e. the individual's perception of her ability to actually perform the behaviour (Ajzen 2002). Thus, "[a]s a general rule, the more favourable the attitude and subjective norm, and the greater the perceived control, the stronger should be the person's intention to perform the behaviour in question" (Ajzen 2002). The three components of an intention can be modelled as a function of attitudinal, social, and demographic variables (Kiesling et al. 2012).

In the model two key elements determine the decision of agents to adopt or not adopt solar: an attitudinal component ("attitude") and a control component ("control"). A social network model is embedded within the attitudinal module. As the model cycles forward in

[8] Perceptions about social expectations and pressure.

time, both the attitude and control attributes of all agents evolve based on interactions with other agents (in respective social networks) and/or feedback from the environment. The *decision criterion* is that both an agent's attitude and control attributes must be above certain respective thresholds before she adopts solar. The empirical case supports the formulation that attitude and control variables regarding solar evolve independently.



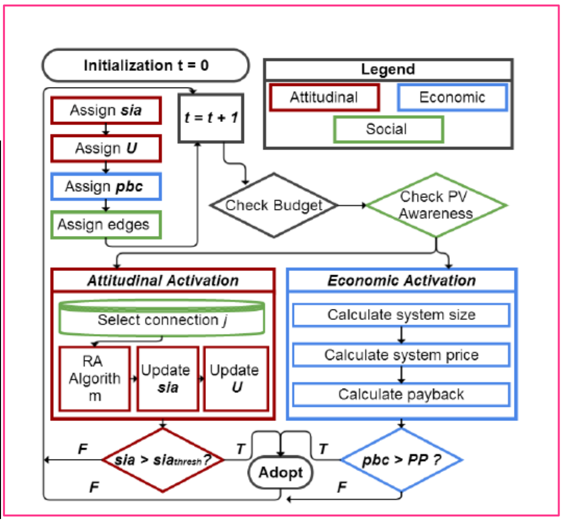


Figure 12. Theory of planned behaviour on the left[9] and the structure of the model realizing the theory is on the right (Rai and Robinson, 2015)

In its standard form TPB is formulated as a *static* model of behaviour: at a specific time, TPB maps measures of attitude, subjective norms, and perceived behavioural control (pbc) onto intention, and intention onto actual behaviour. TPB does not specify how these variables evolve over time allowing intention to change. Since in reality these measures are not static, incorporating TPB in ABM requires complementary means of evolving agent variables. The dynamic aspect in the control component of agent behaviour comes from the *changing economics of solar*. Furthermore, the Relative Agreement (RA) algorithm is used to model the process through which agent attitudes and uncertainties around those attitudes evolve through agent-agent interactions.

4.3.2. Perceived behavioural control, pbc

Simple payback was the most commonly used financial metric by solar adopters surveyed in the study area (Rai and McAndrews 2012; Rai and Sigrin 2013). Accordingly, pbc_i is calculated for each agent *i* as the upper bound for payback period of investing in a solar system: an agent *i* compares her pbc_i with the empirical payback at the current time period PP_{it} and, assuming that she is already above the attitudinal threshold (see below), adoption takes place only if the payback is lower than pbc_i, that is:

$$PPit < pbc_i$$

pbc_i is assumed to be an individual time invariant attribute of an agent over the simulation period.

[9] www.utwente.nl, 14.06.2016

Payback is calculated as a function of the value of the electricity produced by the solar system (*e*), the unit price (*p)* of the solar system (in $/Watt), utility rebates (*R*), and the federal investment tax credit (*ITC*) for each time period *t*, and the annual system electricity generation *G* (in kWh/kW, calculated based on site-specific irradiance, i.e., a source for heterogeneity):

$$PP_{it} = (p_t - R_t - (p_t - R_t) \times ITC_t)/(G_i \times e_t).$$

PP is only affected by changes in prices and rebates. *PP* is computed independently of any physical constraint owing to tree-cover, which, as described below, is accounted for through *pbc*. All other variables except p_t in equation above are known for each agent. p_t is a function of time only.

Agents' *pbc* is modelled as a function of financial resources and the relevant physical features of the house. The home value (*W*) is taken as a proxy for the financial resources available to the agent. The relevant house-feature quantities are size of the house (*s*), tree-cover (*T*), and irradiance received (*I*). Tree-cover and the amount of sunlight received (including any hill shade) may be expected to impact the perception of the financial viability of installing solar.

$$pbc_i = \alpha_0 + \alpha_1 \left(I_i + W_i^* - \left(\frac{T}{s}\right)_i^* \right),$$

where *W** and (*T*/*s*)* denote the weighted *W* and *T*/*s* (the tree-cover ratio), respectively. The weighting is necessary in order to account for differences in the scales of each of the components: *W* and *T*/*s* were made comparable to irradiance by assigning weights such that the medians for *W** and (*T*/*s*)* were equal to the median of *I*.

By incorporating multiple relevant components, *pbc* more fully captures the complexity of solar economics. The calculated *pbc* values resulted in 86.6% correct predictions for the *PP* < *pbc* rule. This is a good result, given that the equation for pbc uses only basic publicly available information and there is no fitting associated with the choice of variables (*I, s, W,* and *T*) that go into computing *pbc* or with their functional forms. Previous studies (Rai and McAndrews 2012; Van Benthem et al. 2008) have found that at early stages of PV adoption there are indeed a segment of customers who adopt PV primarily for environmental reasons, even when the economics may be unattractive.

4.3.3. The attitude module sia

TPB posits that an individual's attitude towards behaviour arises from behavioural beliefs, i.e., beliefs of the individual about the likely outcomes of the behaviour and her evaluation of those outcomes (Ajzen 1991).

The attitudinal module is driven by two dynamic, heterogeneous attributes: attitude (*sia*) and uncertainty about the attitude (*U*). The value of these variables for each agent varies over time making initialisation difficult.

Due to the lack of micro-data from the entire population of *N* households in the study area it was decided to express *sia* in terms of publicly known variables. *sia* is modelled in two parts: The function *f()* describes the relationship obtained in the estimation without the geographical dimension. It is defined by home parcel size *s*, ratio of tree-cover to home value *(T/W),* and home value per unit size *(W/s)*:

$$sia_i = f(s_i, T_i/W_i, W_i/s_i) + m_i(x,y) + \varepsilon_i^*(x,y) + \delta_i,$$

The second part consists of two elements, $m_i()$ and $\delta_i()$, regarding geographical location and the residual error term $\delta_i()$ accounting for variation in *sia* not explained by the publicly available data or geography.

Geographical location may give rise for unobserved attitudinal heterogeneity for two reasons: first, geography may serve as a good proxy for additional socio-economic demographic variables not captured directly in the model, but which do impact attitudes (for example, education); and second, because attitudes may be expected to converge locally due to targeted marketing or neighbourhood information exchange, for example through neighbourhood associations or community organizations (Noll et al. 2014).

4.3.4. Social network

Attitudes evolve in the agent-agent interactions. These interactions depend on the structure of the social network. At each time step agents' attitudes about the technology (sia) and the uncertainties around those attitudes (U) are modified through interactions with other agents to account for opinion dynamics in the behavioural model. Agent attitudes develop dynamically via agent-agent interactions modelled according to the Relative Agreement (RA) algorithm in which gents are only influenced by other agents with relatively similar attitudes.

At each time step, pairs of agents i and j interact, where i influences j. The choice of which agents interact is determined by the social network model: households are placed in small-world networks (SWN) where the majority of their connections are geographic and economic neighbours: live nearby and have similar wealth characteristics.

4.3.5. Model variations

Using the general framework described above four model variations is developed: ''Base-case'', ''Simple Environment,'' ''Random Fitted,'' and ''Economic Only.'' These four model variations were chosen on the basis of empirical and theoretical relevance and represent significantly differentiated modelling approaches. The Base-case is defined first, and the other models are derived from it by stripping down specific components and variables, thus quantifying the effects of increased simplicity or lack of empirical data in terms of fitting and validation.

The **Base-case** model is the full model that uses all model components (attitudinal, economic, and social networks) as described earlier. In addition, the Base-case model uses empirical distributions from the integrated dataset for initializing all agent states and for the empirical description of all environmental factors at the household-level.

The **Simple Environment** model was created in order to study the impact of using aggregate insolation data rather than using the simple average insolation value for the city. As a result, for all agents the value of G was 1361 kWh/kW/year – the electricity generated per kW of a solar PV system per year using city-level average insolation value. Because insolation does not vary by household only home value W_ and the tree cover ratio Tr_ were used in calculating the pbc index.

To test the importance of social interactions and household attitudes the social component of the Base-case is left out in the **Economic Only** model. The decision to adopt in this model was thus based only on the financial (control) criterion: each agent's comparison of their perceived control pbc against the payback PP on a solar system at a given time.

In the **Random Fitted** model empirical distributions are not used to initialize the agents' state but these distributions are approximated using random distributions with variable parameters (i.e. shape and scale, or mean and variance). Uniform, normal, poisson, beta, and gamma distributions were used for the pbc; sia, payback period (PP), and agent uncertainty (U). The end result is that agent state variables are realizations of the specified random distributions: for example, pbc, rather than being determined by equation, is determined by a random draw from a Poisson distribution with an expected value of 3. Finally, the social network model is also random using Erdos–Rényi random graph, wherein any two agents are equally likely to be connected in the social network.

4.3.6. Results

Parameter values were chosen though a fitting process to minimize the objective function of the model, namely the root means squared error (RMSE) in the cumulative number of installations. The models were then compared in three dimensions: temporal, spatial and demographic. The cumulative number of solar systems installations is used for fitting.

Agent-based simulation is a computationally intensive approach. Here it means that the simulation results have been produced in a supercomputer at the Texas Advanced Computing Center (TACC). Depending on the exact specification, each batch (1 batch = 100 simulations) took between 20 and 35 min to execute.

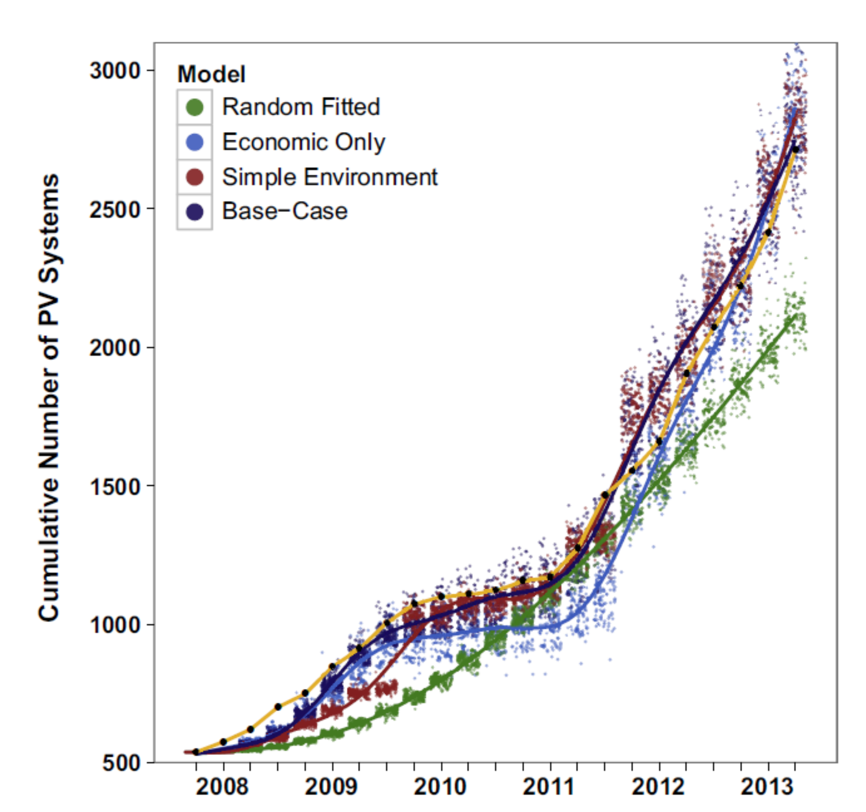


Figure 13. Base-Case, Simple Environment, Random Fitted, and Economic Only model predictions of cumulative solar installations between Q1 2008 and Q4 2013, after fitting. The yellow line and black points shows the empirical adoption curve used for fitting. Semi-transparent coloured points show individual simulation run outcomes (100 runs per model) while solid lines show the expected value of the 100-run batch as a whole for the corresponding model. (Robinson and Rai 2015).

Although the Economic Only model, which uses only two parameters and includes only a financial criterion in agent decision rules, it reproduces the three major structural components of the empirical diffusion curve (moderate growth early, a period of very slow growth from Q2 2009 to Q1 2001, and a period of rapid growth 2011–Q2 2013). This reveals two important findings (Robinson and Rai 2015): First, home value, the tree cover, and insolation are good predictors of the solar installation decision. Second, a simple economic model is likely adequate *if the goal is to predict adoption levels over time*. This finding is somewhat surprising (Robinson and Rai 2015) given the significant non-technical barriers associated with solar adoption beyond the system cost.

The Simple Environment model replicates the temporal adoption patterns well, but it is clear that the model places too much emphasis on the wealth of agents, as opposed to the generation potential of the system. The varied terrain, steep slope, and high tree cover in some parts of the study area make them difficult areas for solar adoption. But that is not captured well by the Simple Environment model, which only uses a city-level aggregate value for insolation. The use of insolation at the household level in the Base-case model generated significant improvement across all validation metrics.

However, the authors note that to move to models that are predictive of complex disaggregated features such as spatial and demographic patterns, social and attitudinal components need to be integrated into the modelling effort.

4.4. Conclusions on agent-based models

Agent-based models are known to be computationally heavy and greedy for detailed data the example presented confirms these features. On the positive side, the models can usually be defined with easy-to-understand concepts and the decision-making logic of the agents can at best be constructed so that they resemble those of everyday life.

Naturally, the usefulness of a model is dependent on the particular use the model is put to. To produce relevant answers the model has to have relevant components and dimensions in it. In this respect the need for detailed data referred to above pose problems that may be difficult to overcome.

Diffusion models typically aim for predictive accuracy. However, innovation diffusion predictions can only be validated ex-post, and so the results are at least to some extent speculative thought experiments until data for validation becomes available. In reality, futures are not predictable.

To avoid the pure speculative characteristics of the model results one may take “deep uncertainty” (Lempert 2002) as a starting point. When applying this paradigm the stakeholders need not to agree on the “right” model or parameter values but use all relevant models and values in the analyses. Then the analyses would use exploratory modelling approach where thousands of scenarios are used to represent plausible futures and criteria such as robustness, resilience and stability are used to compare alternative policies. Decisions are ranked by probability of achieving desired outcomes rather than optimisation or efficiency.

5. Concluding remarks

5.1. Synthesis

A move towards 100 % renewable energy based system highly based on solar and wind as a high-level topic of the Neo-Carbon Energy (NCE) project is clearly linked with behavior of different actors in society. Actor analysis for Neo-Carbon project is motivated by arisen need for “identifying & adding actors” to Neo-Carbon scenarios. The NCE scenarios are analyzed and produced by several approaches, however, often lacking thorough consideration of actor viewpoint. Generally, actor analysis is also needed for any kind of real dissemination, e.g. for policy recommendations and/or development of an action plan. The actor analysis can reveal influences in actors’ goals, strategies, and options.

In the first funding period, methods to identify and add actors in Neo-Carbon framework were reviewed and developed and actor analysis experiments conducted accordingly. These efforts are mainly based on WP1 scenarios by UTU/FFRC based on foresight methodologies and also on collaboration with the WP3 research on business cases. Thus, the Neo-Carbon actor analysis framework can be described as “analysis based on analysis”. Based on a word analysis of WP1 scenarios and stakeholder matrices drafted, the key actor types and differences between the scenarios with respect to actors could be suggested. Based on *Table 16* that shows occurrence frequencies, a hypothesis of relative significance of actors could be straightforwardly produced. Furthermore, through the applied stakeholder matrix framework, five different groups of stakeholders based on when in the development process each group is most active, and which kind of influence it can exercise, could be suggested in somewhat more preliminary manner.

Table 16. Suggested two most important actor groups in scenarios partially reproduced from Table 5. Manual filtering is included to computer-aided searches.

Significance	**Radical startups**	**Value-driven techemoths**	**Green DIY engineers**	**New consciousness**
“Most important”	**Startup(s), companies**	**Companies, techemoths,** energy	**Communities, people**	**People,** global, nature
”Intermediately important”	new, **media, investors, consumers, workers, enterprises, freelancers, entrepreneurs, cities**	large, **corporations, civil, people, society, google,** global, **states, apple,** technology, big, **citizens, sector, samsung, rich**	**diy, amateur,** local, self-sufficient, **engineers**	everything, **individuals,** systems, **millennials, citizens, society, humans, biophilia,** energy, system, connected**, communities, eu,** parts, **organisations**

Generally, in the *Value-driven techemoths* and *Radical startups* scenarios, the actor types with power to influence seem to fall under categories of companies, businesses and entrepreneurs.

In the *Radical Startups* scenario, **startups, companies, investors, workers, cities**, and **entrepreneurs** are suggested as key actor types. Reflecting to scenario description, these actors can be seen as potentially having a role in the field of small-scale and innovative energy solutions, for example**. Media, freelancers** and **consumers** are suggested as categorized as other stakeholders identified.

Value-driven techemoths scenario considers **large technology companies** "Techemoths" as main drivers of the development as Google, Facebook, Apple and Samsung are mentioned as exemplary of this type of companies in the text (Heinonen et al. 2015). It seems natural to assess that strategies and actions of these type of giant companies strongly outline the development towards Neo-Carbonized world in the scenario.

In *Green DIY engineers* scenario, relatively few actors are identified in comparison to others. As the nature of the scenario as being driven by self-made and communal efforts, **local communities, people**, and "**diy engineers**" are suggested as key influencers in the scenario.

In *New consciousness* scenario, global systems face a radical transformation and as the actors identified are most diversified, key single actors running the transformation are more difficult to identify on a basis of stakeholder matrix. However, the role of international collaboration and global systems is assessed as evident. International organizations can be seen as enablers of this development.

In the current study, the goal of the word analysis was not to deeply analyze the actors based on draft versions of storylines. Such in-depth analysis would include e.g. analysis on why would there be a larger number of actors in scenario X than in scenario Y, or what would be the value changes of individual actors compared to current. Instead, the motivation for the experiment was to study how the method would serve a design of multidisciplinary approach, where both techno-economic and societal aspects are tackled. In this respect, it was encouraging that a long list of suggestions actors could be described that seemed to roughly be in line with the ideas by the authors. Guidelines as unambiguous as possible in word analysis, however, are recognized as a desired characteristic for subsequent development of this type of analysis.

In parallel to word analysis based experiment, collaboration was made with WP3 research to include and utilize results from concrete business cases in the actor analysis. The aim was to identify the key actors of Neo-Carbon energy system based on WP3 expertise and results on different Neo-Carbon concept profitability. As a first result, the following "actor archetypes" were identified with different strategies and drivers on the energy system transition towards Neo-Carbon type.

- **Big, established companies** actively keeping the same market in an environment of holistic system change (e.g. moving away from fossil fuels).

- **Startups**, "better product" as a driver. **Young, agile companies**. Example: renewable wind and solar fields and associated Power-to-Gas technology.
- **Industrial passive adapters** – the primary product being elsewhere.
- **Do-It-Yourself**. For example, **small-scale inventors with a passion on technology**, demonstrations, and new gadgets. **Single-house owners** in central role; the role of slow adapters/ forerunners.

It was observed that the actors identified based on societal scenarios storylines described the actor landscape somewhat more generally compared to more specifically electricity or energy oriented literature as presented e.g. in IRENA (2015). To get the energy sector more thoroughly included in the next phases of the project, further collaboration with WP1 market design studies, WP 3 business cases or external actors actually operating in the field might provide well-founded approaches for this.

Based on actor analysis conducted, different types of actor networks were characterized from NCE scenarios and the results suggested key variables for further analysis and quantitative modeling. That is, each of the considered scenarios were seen to have different profiles with regard to following variables: Key actors ("who"), "How" (motivation), Number of actor types, Number of actors (decision-making entities), and Network characterization. This effort can be seen as an initial effort towards social network analysis.

Actor analysis methods were identified to often being based on interviews, workshops, focus group discussions, questionnaires and other qualitative methods. Often, the application of these methods concerned local and more specified questions rather than global megatrends. Here, further collaboration with the NCE business case studies – and potentially the actual identified key actors - might provide with the most promising opportunities in deepening the actor analysis. Also, deepening qualitative description is a direction worth consideration.

To consider approaches for quantification in actor analysis related problems, agent based modeling tools were explored and studied. Agent-based models are known to be computationally heavy and greedy for detailed data the example presented confirms these features. On the positive side, the models can usually be defined with easy-to-understand concepts and the decision-making logic of the agents can at best be constructed so that they resemble those of everyday life.

Especially related to NCE field, the agent-based method was found to have recently been utilized in cases with a high number of stakeholders and decision-makers such as modelling of penetration of small-scale PV panels in districts, which was reviewed as an example. The main issues in describing individual agents were models of consumer adoption process and the influence of consumer heterogeneity. Also, structures of consumers' social networks were found out to having a great influence and having been widely studied in agent-based literature.

5.2. Thoughts on next steps

To complete the actor analysis and following Wangel (2011), *Social network approach,* and *Governance model approach and/or policy and change approach* are one possible of an approach to be executed in phase 2 of the Neo-Carbon project. The governance model approaches latter includes a link to governmental, EU, and global targets/policies, and also link to WP2 energy system analysis. That is, timelines and potential of technologies as result of WP2 studies are planned to be utilized in the approach.

An interesting set-up for further analysis is to compare the results obtained by different approaches. Do the different methods suggest similar results, or can conflicts or shortcomings be revealed?

As initial experiments demonstrated the feasibility of word analysis to describe and classify the actor based on storylines, if used in the following phases, one needs to consider the characteristics of source material. For example, the nature of scenarios presented in Heinonen et al. (2015) implies four different transformative scenarios describing a world radically different from that of today. But, it is relevant to discuss whether the actors identified from that kind of scenarios form the most efficient base in designing an action plan. As the time horizon in transformative scenarios considers radically different long-term futures, are short-term horizon and technical feasibility considered enough for designing an action plan? Or, are the actors identified radical or influential enough to make a transformation happen? Or should we continue by identifying new actors that are needed to realize these four scenarios?

These scenarios, presented more in detail in Heinonen et al. (2015), are enrichened as the Neo-Carbon Energy project proceeds. Foresight tools, such as a second round of horizon scanning and an international questionnaire on renewable energy forerunners, are used**.** However, to complement the transformative scenarios further, some other kinds of scenarios could also be looked at. Interesting actors could also be identified from renewable energy related visions. What is more, emerging findings from the business cases and techno-economic energy modelling of the Neo-Carbon Energy project may yield further considerations.

As a targeted outcome of the actor analysis, a robust action plan with needed stakeholders and other actors will be created. Especially valuable in the Neo-Carbon approach is that both technological and societal as well as policy dimensions are included in the analysis. These characteristics are often lacking from quantitative backcasting scenario studies. In the Neo-Carbon Energy project, the objective is to make qualitative scenario-building and quantitative modelling to discuss with one another. These reflections are also relevant, when we wish to understand the actors and their motives in order to achieve an energy transformation.

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