periodica polytechnica

Social and Management Sciences
18/1 (2010) 11–19
doi: 10.3311/pp.so.2010-1.02
web: http://www.pp.bme.hu/so

RESEARCH ARTICLE

Modeling methodologies of synergic effects related to climate change and sustainable energy management

Attila Fűr / *Mária* Csete

Received 2010-01-14

Abstract

The main aim of the present article is to highlight the synergic effects related to climate change and sustainable energy management. Due to our model and given methodology it is possible to examine the relations between the terms mentioned above. In our Knowledge Attributed Petri Net based simulation model the most significant elements are highlighted in question of integrating Cellular Neural Networks and Fuzzy Systems into an object oriented formal description. This methodology implies the importance of holistic approach – namely the usage of predefined risk categories, spreading of causes and effects in physical space – that is crucial in these investigations. Only marginal attention is paid to the synergic effects related to adaptation and mitigation efforts according to climate change. Taking every result into account, this methodologically complex subject is possible to examine from the point of sustainability.

Keywords

Sugeno-type FUZZY · Knowledge Attributed Petri Nets (KAPN) · Cellular Neural Network (CNN) · climate change · sustainable energy management · synergic effects

Attila Fűr
Department of Environmental Economics, BME, 1111 Budapest, Stoczek Str 2., Hungary
e-mail: fuat@eik.bme.hu

Mária Csete
Department of Environmental Economics, BME, 1111 Budapest, Stoczek Str 2., Hungary
e-mail: csete@eik.bme.hu

1 Introduction

In the focus of the present paper there is the examination of the coherence between climate change and sustainable energy management. In our days, there is an increased interest in the topics of both sustainability and of climate change. [6], [17] The most diverse views, facts and ideas are published in relation to these two terms, an endeavor and a phenomenon, respectively, which require the harmonization of viewpoints, cooperation and common thinking [1]. On one hand, this study is intended to help the understanding of synergic effects considering adaptation and mitigation efforts.

Similarly to sustainability, climate change is also more and more often in the focus of attention and discussions [18]. In spite of the fact that the causes connected with climate change are still argued, as well as the phenomena of global climate change, our examination has shown that in accordance with the principle of precaution there is needed some action on behalf of local citizens towards prevention and mitigation of damages or towards the adaptation to climate change emphasizing the synergic effects related to them. However, even everyday people have the bitter experience of the increased frequency of weather anomalies both abroad and within the country, which damages become evident even in numbers, using different damage calculation methods. From the viewpoint of both terms sustainability and climate change a holistic approach is needed to be able to examine the interactions, moreover to find the possible solutions [3]. According to the IPCC report climate change can be one of the biggest dangers, risk of sustainable development. Nevertheless, the third report of IPCC emphasized in relation to sustainability that there can be an advantage in the mitigation of climate change. In the focus of this study there are the interactions between the terms mentioned above, their synergic effects, and the negative and positive externalities on different levels [9], [8].

The methodology detailed in this paper is appropriate to handle the case of synergic effects. There are several methods, models and mathematical concepts investigating the possible descriptions of such complex systems as climate, but there are only few examinations present that focus on the synergistic effect [15]. Most of these investigations analyze special field of synergistic effects [12], and do not offer global methodology. In this paper a new approach is detailed that focuses on FUZZY-like spreading of potentials and risks over Cellular Neural Network, that can be implemented by using Knowledge Attributed Petri Nets [10], [16].

2 Adaptation to and mitigation of climate change

Societies have always had to respond to climate variability and extreme weather events. Many have developed ways of coping with floods, fires and droughts. Recent experience of weather extremes has given these efforts new motivation within countries as well as at the European level. Whilst climate change is a new driver for action, mitigation and adaptation will in many cases be implemented by regulatory modifications of the existing policy frameworks for floods, droughts and the management of water quality.

The IPCC defines adaptation as "adjustments in natural or human systems in response to actual or expected climate stimuli or their effects, which moderate harm or exploit beneficial opportunities" [9].

Adaptation to climate change takes place through adjustments in human and natural systems to reduce vulnerability in response to observed or expected changes in climate and associated extreme weather events [19]. It involves changes in perceptions of climate risk and in social and environmental processes, practices and functions to reduce potential damages or to take advantage of new opportunities. Adaptation is a cross-sectoral, multi-scale and transboundary issue, which requires comprehensive and integrated modeling methodologies (Fig. 1) [21].

Mitigation refers to actions which are able to reduce the man-made causes of climate change e.g. reducing emissions of greenhouse gases, such as CO_2, through energy efficiency and using sustainable solutions of transport and energy.

Both adaptation and mitigation efforts are essential parts of addressing challenges and opportunities associated with climate change. Adaptation mainly addresses the impacts and opportunities related to climate change. Mitigation refers the efforts to limit the human-induced causes of climate change. Moreover the costs of inaction is considered to be much higher than early action related to the possible effects of climate change [20].

Mitigation and adaptation are closely related and should be considered together rather than separately. Sustainable energy management can play important role both in adaptation and mitigation strategies according to the precautionary principle causing several positive externalities and synergic effects.

3 Sustainable energy management

Sustainable energy management is one of the major areas of sections related to sustainable development and can be one of the major tools that is able to cope with the possible effects of climate change. As target and driving force of economy it has to be handled with special respect considering not only economical and social, but also environmental aspects.

According to the study called „Our Common Future" published by the United Nations, there are three main requirements that should be met to keep nature at constant state [22, World Commission on Environment and Development, 1987]:

- the utilization of renewable energy should not exceed its regeneration capacity,
- the utilization of non-renewable energy should not exceed the regeneration capacity of renewable substitutes,
- emission of impurities should not exceed nature's assimilative capacity.

There is also a fourth requirement that is based on natural behaviors, and dynamics of systems. Following this assumption time constant of human activities should be adjusted to time constants of natural processes to ensure system stability [4].

According to these viewpoints of sustainable development sustainable energy management can be defined as robust control of economy and nature that focuses on the following main conditions:

- preventing usage of unnecessary amount of energy,
- increasing efficiency of energy usage,
- preferring most efficient energy sources considering different kinds of utilization,
- usage of local and renewable energy sources, clean technologies,
- minimizing of pollution, or nature related pressures,
- ensuring secure energy supply.

The above mentioned criteria show, that sustainable energy management should be substantial element for regional and global policy. Beyond increasing the proportion of renewable energy producers, it is also very important to pay attention to decreasing the coal-based energy utilization, and to increase economy of energy production and technical efficiency. Without appropriate plans of economy and efficiency relative to energy usage it is unfeasible to increase the number of alternative power plants significantly.

Fig. 2 shows how to integrate the aspects of sustainability into the classical approach of energy management.

Basically sustainable energy management should be handled as a soft system with regard to virtual and physical spaces. Physical space means the location of regions, infrastructure, grids of energy, and way of environmental pollution. Virtual space stands for economy, as subsystem of nature, in which energy management should be integrated into all possible related fields e.g. traffic, agriculture, industry, tourism, communication, etc. Local and centralized data collection and communication is also very important for determining parameters of supervisor controller (state administration), that affects local policy in connection to energy management. Regions – as shown in Fig. 3 –

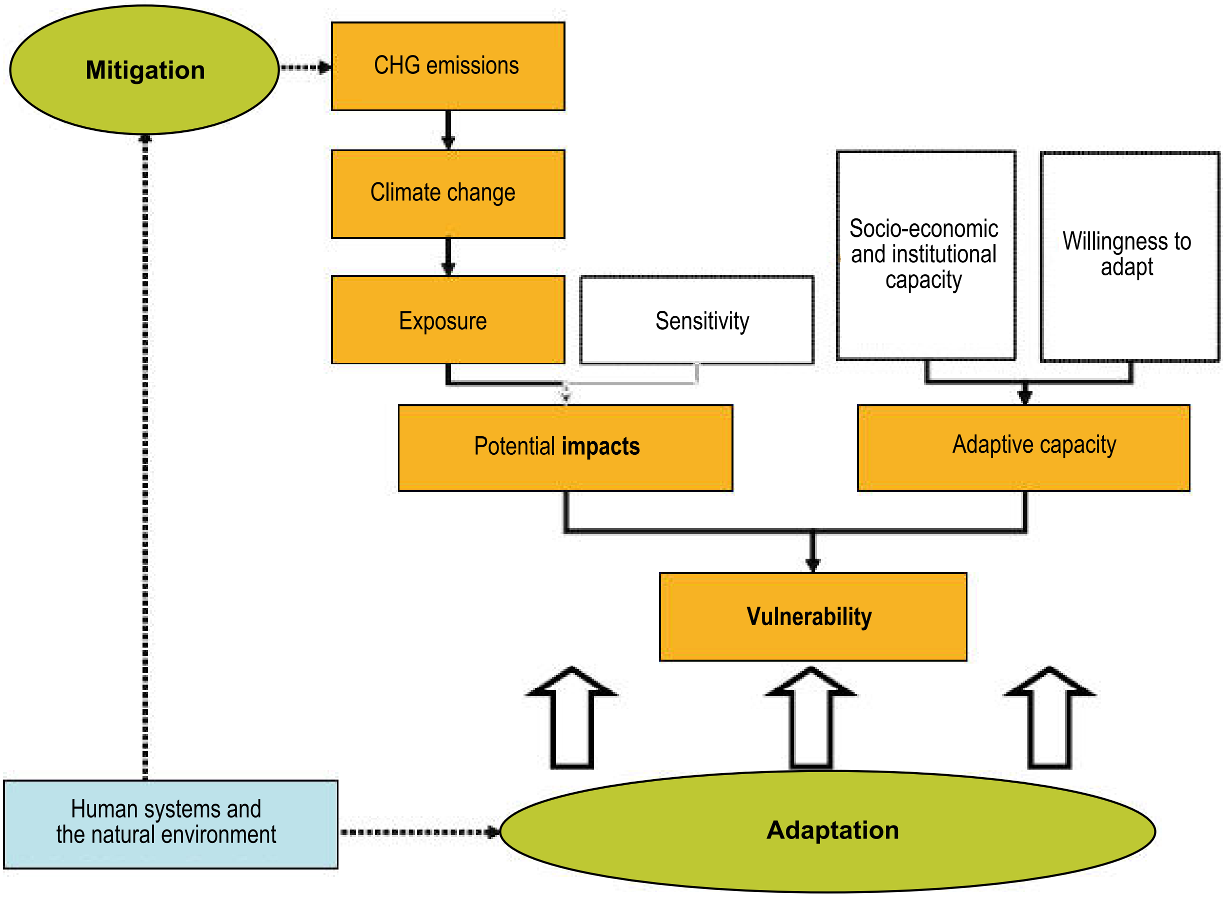


Fig. 1. Conceptual model for climate change impacts, vulnerability and adaptation. Source: [5, EEA (2008), Chapter 6.]

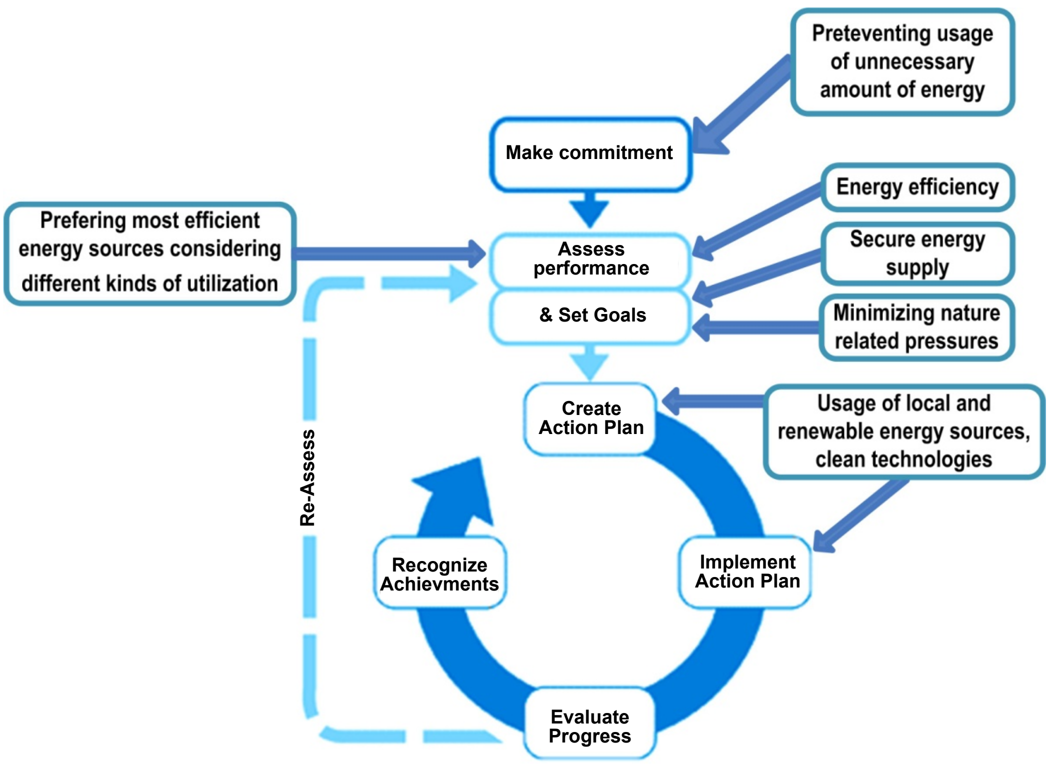


Fig. 2. Sustainable Energy Management. Source: http://www.energystar.gov/

have cellular behavior, neighborhood effect, with fuzzy borders of set with regard to the streaming of energy and materials (e.g. wastes, and nature related pressures) on the physical layer, but on the other side they must be strongly centralized in the virtual space of communication and economy, to ensure adequate feedback mechanisms coming from the supervisor controller (state) [10].

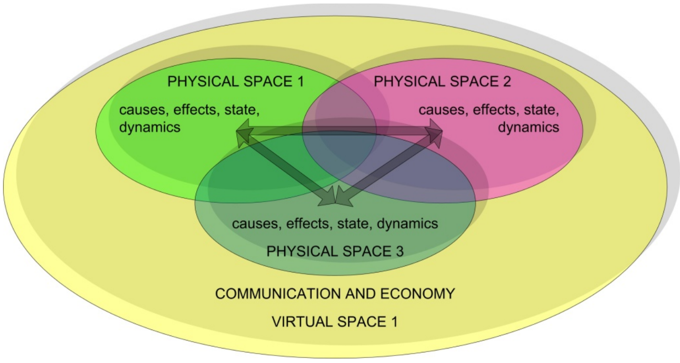


Fig. 3. Cellular behavior of regions embedded into virtual spaces. Source: own compilation

These regions – in the meaning of geographically and economically uniform cellular areas – own their local energy production, which are more or less polluting the local physical area and the neighboring spaces. The pollution causes changes in weather and climate trajectory that indicate other changes in energy management, therefore it is elementary to synthesize adequate model for connecting emissions, weather and climate. Only after that is the examination of synergic effects executable.

4 Basic elements and methodologies

Before delineating the detailed description of the multi-layer simulation model it should be understood that such complex systems as climate or energy systems can be modeled by numerous different ways, but there are only few methodologies that really fit to the natural behavior of real systems, especially if those methodologies have to be integrated into one hybrid model. In case of examining the synergistic effects related to sustainable energy management and climate change two main types of model elements can be defined. The first one is economical layer with energy producers and consumers, and the second one is the climate model layer derived from weather trajectory.

Weather can be defined as a set of all extant phenomena in a given atmosphere at a given time. It also includes interactions with the hydrosphere. The term usually refers to the activity of these phenomena over short periods (hours or days).

Climate is the average and variations of weather in a region over long periods of time.

The climate of any region is largely determined by its geographic position. Four aspects of the geography of a region that influence climate are latitude, the distance from a large body of water, the direction of the prevailing winds and its elevation.

As basic climate attributes the following parameters can be taken into consideration (average values):

- air temperature,
- soil temperature,
- relative humidity,
- barometric pressure,
- wind speed,
- wind direction,
- precipitation,
- solar flux density,
- total solar flux.

The momentary values of these parameters have special trajectory in time according to exact location and the behavior of neighboring areas. These states and changes of weather theoretically can give relevant information about the upcoming trajectory. Practically due to the turbulences and chaotic (or more complex) behaviors of weather it is not possible to carry out predictions without the exact knowledge of initial values. Small differences in initialization can cause large deviations of trajectories, therefore forecasting of weather is limited in time.

Nevertheless climate seems to be more predictable. As a set of average values over long period of time small perturbations of weather trajectory became flattened. Practically climate forecasting is nearly as complex as weather prediction. There are several factors that have significant influence on climate change and probably there are some other factors that are underestimated concerning the caused effects. These small effects often cannot be measured directly but they cause deviation from the main trend. Typically high-risk factors – that cause deviations – are emissions of small quantities of dangerous (e.g. radioactive) materials, or great amount of seemly non-hazardous materials (CO_2).

Emissions are nature related pressures that are measured at the place of origin. Imissions are the impacts of pollution that appear in the affected areas.

Since it is not possible to recognize exact relation between emissions, weather, imissions and climate the usage of impacted risks can be suggested. The risks can be defined over fuzzy sets with e.g. the following names: DANGEROUS, SIGNIFICANT, HIGH-LEVEL, MEDIUM, LOW-LEVEL, UNSIGNIFICANT, etc. For each climate factor different risk variables can be used. In that way the mentioned two model layers can be interconnected through sets of FUZZY Inference Engines. Implication process can be suggested in Sugeno-form, that allows high computational efficiency, has guaranteed continuity of the output surface and works well with optimization and adaptive techniques. As known the prime Sugeno-type FUZZY relation R_i has the following form, where y output membership function is linear [14]:

$$R_i: \quad \textbf{if } x_1 \textbf{ is } A_1^i \textbf{ then } y = ci_1 x_1 + \ldots + ci_n x_n + ci_0, \quad i = 1, \ldots, m \qquad (1)$$

Relation between alternative energy producers and impacted types and magnitude of emissions can be described this way (see Fig. 4).

According to cellular behavior of regions in physical space definition of "spreading-model" becomes also necessary. In that case the risks for climate are represented as spreading phenomena that are able to additively stream through interconnected climate zones causing changes in climate also in far areas. The range of effects can be given by a damping factor that is directly influenced by geographical surface of location. (E.g. high mountains between two neighboring climate zones represent high damping factors.)

The recognition of neighborhood-effect bases the usage of CNN (Cellular Neural Network) description. The CNN concept includes basically grids of elements in matrix form that have connections only to their neighboring cells in a determined environment [2]. There is a radius of the communication defined, that limits the complexity of the grid. If neighboring radius is 1, the connections have a weight in communication of 9 according to the number of neighboring cells and the central cell. These weights are included into the template matrices [13]. CNN equations have in case of state-output the following form:

$$\dot{x}_{ij}(t) = -x_{ij}(t) + \sum_{W^x_{rij}} \mathbf{A}_{kl} x_{ij}(t) + \sum_{W^u_{rij}} \mathbf{B}_{kl} u_{ij} + z_{ij} \qquad (2)$$

$$x'_{ij}(t) = \frac{1}{2}\left(\left|x_{ij}(t)+1\right|\right) - \left(\left|x_{ij}(t)-1\right|\right) \qquad (3)$$

Where $x_{ij}(t)$ time-dependent (state-variable), $x'_{ij}(t)$ is limited state, u_{ij} stands for input variable, z_{ij} is time-independent constant, **A** and **B** are the template matrices. Domains $W^x r_{ij}$ and $W^u r_{ij}$ express r radius environment of x_{ij} and u_{ij}.

Applying CNN methodology in streaming of risks can reveal new aspects that had been weighted insignificant before. This way of communication is not only suited to map the physical streaming of pollution, but is also appropriate to simulate the diffusion of effects in regions (See Figs. 5 and 6). In climate systems alternative connections can be also defined concerning e.g. prevailing winds.

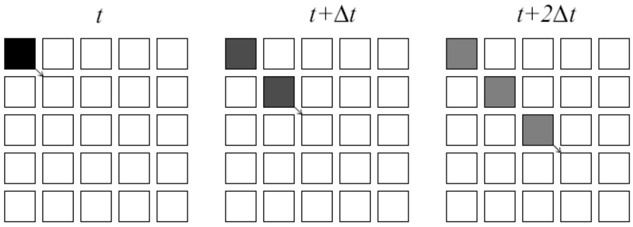


Fig. 5. Streaming of pollution from a high polluted area in South-East direction. Source: [13]

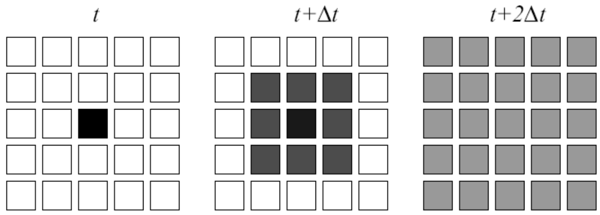


Fig. 6. Diffusion of effects. Source: [13]

5 Knowledge Attributed Petri Net Based Simulation Model

To handle and to connect the mentioned methodologies adequate mathematical concept has to be chosen. The usage of Knowledge Attributed Petri Nets seems to be a natural way to synthetize robust models.

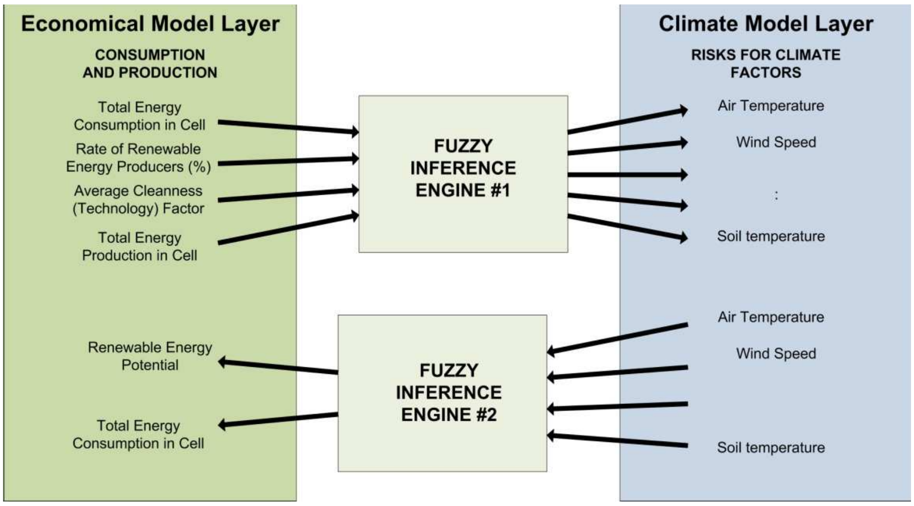
Knowledge Attributed Petri Nets (KAPN) are extensions to the conventional Petri Nets that own all properties of Colored, Numerical, Stochastic and Object Petri Nets [10]. Basically KAPNs are directed graphs that have places and transitions alternating in their nodes. Places are containers that have given capacity in reference to special mobile entities (tokens). Transitions contain the rule base of creating and destroying tokens and parameterize token attributes that carry information from one place to the other one. Directed arcs symbolize the connections between places and transitions therefore they determine streaming of information. In KAPNs numerical, linguistic, symbolic and knowledge attributes can be defined, transition conditions and operations are allowed to contain complex expressions and algorithms, so they are well suited to host mathematical concepts e.g. CNN equations or FUZZY inference engine. [7].

KAPNs are hierarchic so parts of the whole net can be wrapped into objects, therefore details of functioning can be hidden into low-level objects and optimization and modifying of topology can be carried out easily on the top model layer. Model modifications during runtime are executed by intelligent demons that are monitoring the emissions of far cells and the distances of transport and suggest changing the topology of network so that requirements of sustainable energy management become fulfilled (e.g. preferring local energy usage against transport, minimizing energy consumption) [10].

The investigation of synergistic effects related to climate change and sustainable energy management can be demonstrated by the following loop. If any relation between usage of energy and climate change can be assumed, the following experimental frame can be suggested.

- Cells are representing physical spaces (regions) that have given climate and own their given energy consumption and production.
- According to CELL_m top (climate) and bottom (production, transport and consumption) layers two FUZZY inference engines (FIE_{m1}, FIE_{m2}) can be formalized. The first one defines relation as function of risk factors for climate (e.g. risk

Fig. 4. FUZZY relations between economical and climate model layers. Source: own compilation



of change in temperature) with outcome of changing in energy consumption (Eq. 4). The second inference engine gives information about the potentially generated risk related to climate factors coming from the change of energy production in CELL_m (Eq. 5).

$$\Delta\textbf{Energy consumption in } CELL_m = FIE_{m1}(\textbf{Risk Factors of Climate in } CELL_m) \quad (4)$$

$$\textbf{Risk Factors of Climate in } CELL_m = FIE_{m2}(\Delta\textbf{Energy production in } CELL_m) \quad (5)$$

- Cells on the bottom layer are connected through the transport of necessary energy. The connections are symbolized by directed arcs between places defined over KAPNs. The amount of transported energy is determined by the demand arisen in CELL_m and the capacities of the possible suppliers that are directly influenced by the climate and the non-renewable production.
- Each Cell on the bottom layer contains Generators (energy production units) and Drains (consumers). On high demand of energy consumption also Generators of far cells are involved therefore emissions and risks are transferred to the far area.
- Cells on the top layer symbolize the climate as separate zones (KAPN places) interconnected with each other through transitions that are formalized based on physical laws, and a priori information (such as wind direction, flow of rivers, or microclimate). The places contain the tokens that own attributes as risks of climate factors mentioned previously. These risks are spreading through the network of the top model layer.
- Risks, uncertainties in climate factors in the top model cells indicate less reliability in operating on schedule related to renewable producers, and also indicate more usage of non-renewable energy. Usage of less renewable energy and more usage of non-renewable energy cause increased risk for climate factors in CELL_m and increased risk in the related (directly interconnected) far cells also.
- Inefficiency of transporting energy from great distances to specific cells can be represented by various destroy rate of tokens (energy units) as function of distance.
- As main objective of the simulation model identification of synergistic loops can be mentioned. These loops can be found easily by monitoring e.g. the most increased energy consumptions and the highest levels of generated risks amongst cells. If there is a direct connection between these cells on the bottom (energy transport) layer and the mentioned cells are within an r-radius environment of each other on the top (climate) model layer (should be chosen adequately considering damping factors for spreading risks) then synergistic loop has been found.
- Over the model two main intervention points can be defined. The first one is minimizing the sum of energy consumption, the second one is minimizing the sum of transfer distance of energy (see requirements for sustainable energy management). Both optimizations are carried out beside the boundary condition of minimizing the sum of total risks in climate change. These optimizations are running competitively during simulation with an effort of global optimization, therefore these methodologies own similarities to genetic algorithms.

Based on this model examination of synergistic loops between spreading of climate change risks and energy management become possible. Through model simulation sustainable energy producing and consumption model can be found for cooperative cells minimizing the total risks of climate change.

6 Typical synergistic loops

The previously highlighted model helps in understanding the couplings and synergistic loops between two complex systems. To show some of the identified synergistic loops following examples can be given.

1 City with high average air temperature in summer → More usage of air condition in rooms → Higher temperature on streets and more usage of non-renewable energy sources →

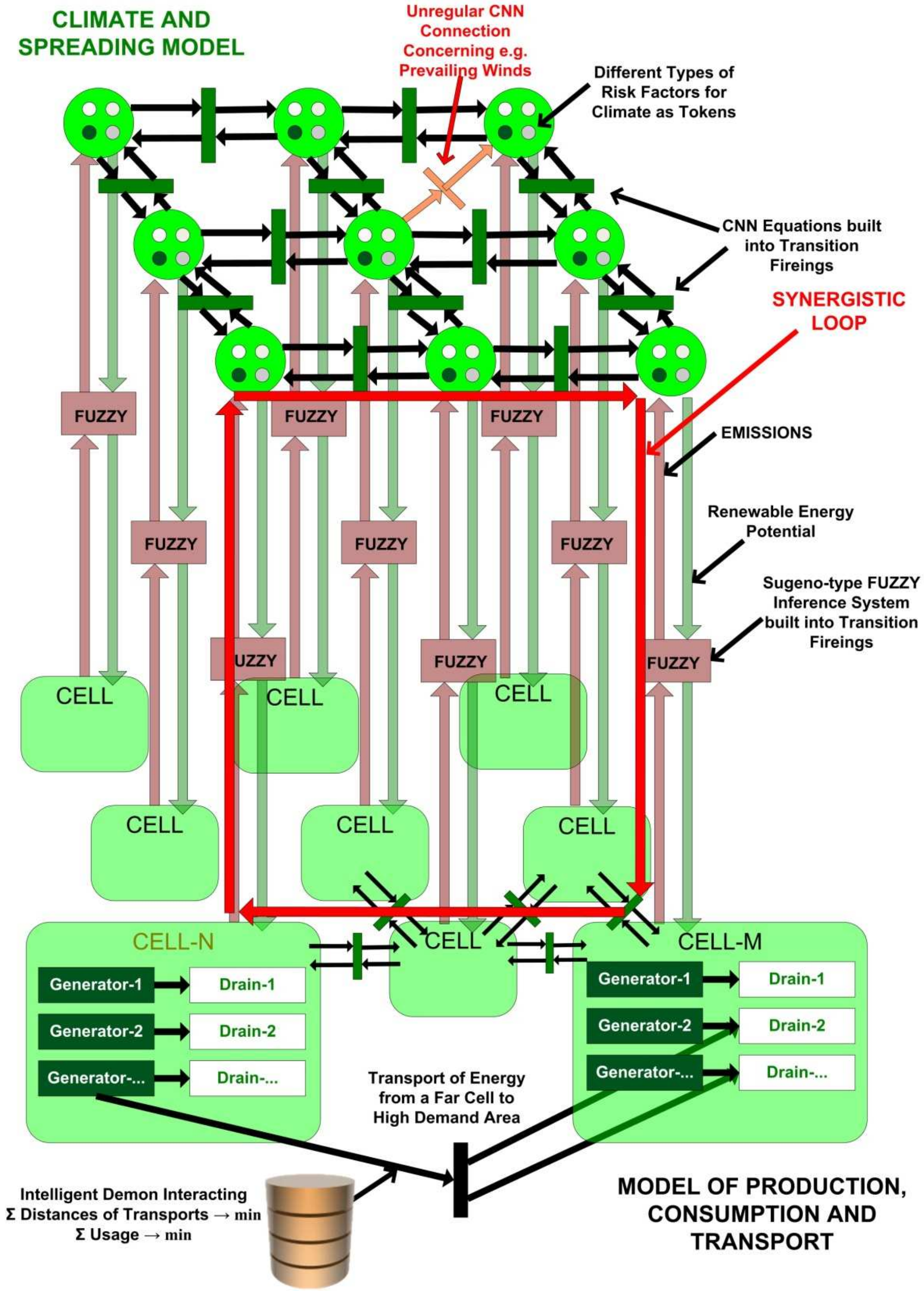


Fig. 7. Model of climate change and sustainable energy management (own work)

Fossil power plant nearby → Bad air quality → Spreading to City → Less usage of natural air ventilation, closed windows → More usage of air condition

2 City with high average air temperature in winter → Less heating → Less pollution during winter → Decreasing risk for raising the air temperature

3 Considering case 1 and 2 totally used energy during the seasons determine if the loop goes into a positive or into a negative feedback. If energy usage in summer is greater than energy usage in winter then the feedback is positive, no sustainability can be reached until the number of renewable energy producers is changed or usage of air condition is reduced or sustainable substitute technologies are used [24]. If energy usage of 1 is smaller than energy usage of 2 then the loop goes into stable state that can be handled over extended period of time.

As delineated various loops can be found over different ranges of time or physical spaces. The second example shows how seemly non-hazardous amounts of risks can become significant through summarization.

4 Countries with great demand on energy usually generate pollutions in different areas, also far from themselves → If there are no significant drains nearby the loop risks are accumulated → If cyclic behavior of climate in physical space can be assumed then accumulated risks are transferred to the place of origin (closed loop) where demand is great on energy (see Fig.8).

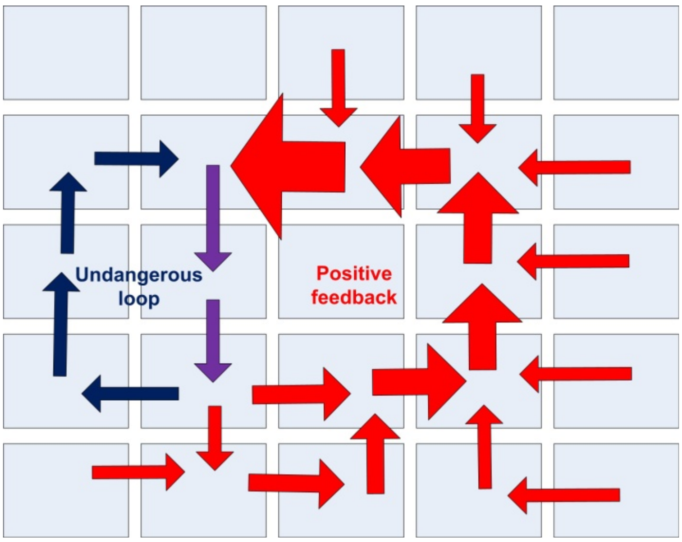


Fig. 8. Accumulating risks over closed loop (own work)

As typical example for closed loop is the situation of countries nearby the Gulf Stream. In North-West Europe and north-eastern area of the United States energy consumption is high but climate is fragile due to Gulf Stream that is extremely endangered by global climate change caused (amongst others) by these countries.

7 Conclusions

The main aim of our paper was to highlight the connection between climate change and sustainable energy management. According to the complexity of problem, special way of modeling and simulation can be suggested, wherein combination of soft-computing techniques is implemented. Due to the obscurities of assigning numerical values and equations, usage of Sugeno-type FUZZY model can be chosen to define verbal risk values, and rule-base according to empirical and anticipated models. Spreading of causes and effects in physical space can be mapped into Cellular Neural Networks that can be implemented on Knowledge Attributed Petri Nets (KAPN), that are able to merge different mathematical concepts into one robust model.

The model shown in this article might be useful to emphasize the synergic effects related to sustainable energy management for all the stakeholders including decision makers, inhabitants, NGO's, employees, farmers and investors as well. Furthermore, it underpins all of the impacts from the holistic aspect of sustainability related to climate change and sustainable energy management. It seems to become evident from previous experiences and investigations that adaptation to climate change can play a significant role not only in the implementation of sustainability but in mitigation as well. It is quite impossible to foster sustainable development without taking the dimension of climate change into consideration. The synergic effects related to climate change and sustainable energy management, the coherence and connections between sustainable and climate strategies on different levels can get on in the near future as a positive effect in long term.

This wotk is connected to the scientific program of the „Development of quality-oriented and harmonized R+D+I strategy and functional model at BME" project. This project is supported by the New Hungary Development Plan (Project ID: T'AMOP-4.2.1/B-09/1/KMR-2010-00002).

References

1 **Sneddon C, Howarth R, Norgaard R**, *Sustainable development in a post-Brundtland world*, Ecological Economics, **57**(2), (2006), 253–286, DOI 10.1016/j.ecolecon.2005.04.013.

2 **Chua L, Yang L**, *Cellular Neural Networks Theory*, IEEE Transactions on Circuits and Systems, **35**(10), (1988), 1257–1272, DOI 10.1109/31.7600.

3 **Csete M**, *The Synergistic Effects of Adaptation To Climate Change On Local, Subregional Level*, Global Conference on Global Warming (Istanbul, Turkey, 2008), 2008, 1244–1249.

4 **Daly H**, *Uneconomic growth: in theory, in fact, in history, and in relation to globalization*, Ecological Economics and Ecology of Economics: Essays in Criticism, Edward Elgar Publishing, Northampton, MA, USA, 1999, 1999, 8–24.

5 **EEA**, *Impacts of Europe's changing climate – 2008 indicator-based assessment. Joint EEA-JRC-WHO report*, European Environment Agency, Copenhagen, 2008, available at `http://reports.eea.europa.eu/eea_report_2008_4/en/`.

6 **EU SDS**, *Review of the EU Sustainable Development Strategy (EU SDS) – Renewed Strategy*, 2006, available at `http://ec.europa.eu/sustainable/docs/renewed_eu_sds_en.pdf`.

7 **Fűr A, Tóth Á**, *Idegsejthálózat működésének Petri Hálós szimulációja (Simulation of Nerve-cell Network by Knowledge Attributed Petri Nets)*, Alma Mater, **9**, (2005), 311–344.

8 **IPCC**, *Intergovernmental Panel on Climate Change, Fourth Assessment Report*, 2007, available at http://www.ipcc.ch/.

9 ______, *Intergovernmental Panel on Climate Change, Third Assessment Report*, 2001, available at http://www.ipcc.ch/.

10 **Jávor A**, *Demon Controlled Simulation.*, Mathematics and Computers in Simulation, **34**(3–4), (1992), 283–296, DOI 10.1016/0378-4754(92)90006-3.

11 ______, *Knowledge Attributed Petri Nets*, Systems Analysis Modelling Simulation, **13**(1–2), (1993), 5–12.

12 **Kirby R, Beaugrand G, Lindley J**, *Synergistic Effects of Climate and Fishing in a Marine Ecosystem*, Ecosystems, **12**(4), (2009), 548–561, DOI 10.1007/s10021-009-9241-9.

13 **Bulla M**, *Komplex környezetállapot-értékelő szakértői rendszerek metodikai fejlesztése (Methodological Development of Complex Environmental Assessment Systems),* SZIE, Győr, 2004.

14 **Lantos B**, *Fuzzy Systems and Genetic Algorithms*, Műegyetemi Kiad'o, Budapest, 2002.

15 **Russel B, Thompson J, Falkenberg L, Connell S**, *Synergistic effects of climate change and local stressors: „CO_2 and nutrient-driven change in subtidal rocky habitats"*, Global Change Biology, **15**(9), (2009), 2153, DOI 10.1111/j.1365-2486.2009.01886.x.

16 **Russel S, Norvig P**, *Artificial Intelligence: A Modern Approach*, Prentice Hall, Upper Saddle River, New Jersey, 2002.

17 **Scientific Expert Group on Climate Change (SEG)**, *Confronting Climate Change: Avoiding the Unmanageable and Managing the Unavoidable.*, 2007.

18 **SEC 1417**, *Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions – Towards an EU response to situations of fragility – engaging in difficult environments for sustainable development, stability and peace*, 2007.

19 **SEC 849**, *Green Paper from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions – Adapting to Climate Change in Europe - options for EU action*, 2007.

20 **Stern Review**, *The Economics of Climate Change*, 2006, available at http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/stern_review_report.cfm.

21 **Uhel R, Isoard S**, *Regional adaptation to climate change: a European spatial planning challenge*, Inforegio Panorama, EU Regional Policy, 2008, available at http://ec.europa.eu/regional_policy/sources/docgener/panora_en.htm.

22 **World Commission on Environment and Development**, *Our Common Future*, Oxford University, Oxford, New York, 1987, ISBN 0-19-282080-X.

23 **Álmos A, Horváth G, Kóczy A, Győri S**, *Genetikus algoritmusok*, Typotex Kiadó, 2003, ISBN 978-963-9326-45-3.

24 *Air conditioning in a world of climate change*, 2007, available at http://www.modbs.co.uk/news/fullstory.php/aid/3447/Air_conditioning_in_a_world__of_climate_change.html.