Modeling for Sustainable Development (MPDD) Chair

Provisional research program 2014-2018

Research perspectives

Initial ambitions confirmed, solid foundations to build on

The International Center for Research on the Environment and Sustainable Development (CIRED) and the MINES ParisTech Center for Applied Mathematics (CMA) propose to continue the Modeling for Sustainable Development (MPDD) Chair because of the following three advances:

- Both teams have considerably expanded and strengthened their modeling scopes, for global, national and sectoral models;
- They have established a strong French presence in scientific and expert networks on energy-climate issues;
- The MPDD Chair has developed a recognized 'brand identity' on prospective modeling, illustrated among other things by the success of its events.

CMA and CIRED propose to reaffirm the Chair's initial objectives by reformulating them as follows:

- Build up a ***long-term prospective platform*** with the two teams to aid decision-making on economics-resources-climate and facilitate ***methodological progress*** in prospective work;
- ***Inform debates*** on major **sustainable development** issues drawing from the combined expertise of the two teams, and from questions of general interest identified with the Chair's partners, or questions specific to some of the partners;
- Make the Chair into a ***scientific coordination center*** for national and international expertise on sustainable development and contribute to fostering a French community of producers and users of model-based prospective work.
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In contrast with other company chairs that put the accent on scientific activities, the MPDD Chair confirms its ambition to develop a research Chair with a focus on devising methods, producing knowledge and building up skills.

The program described below includes projects to be carried out over the next two years, along with projects which may be initiated in the near future, but that will fully get going in a second stage, depending on requests from all or some of the Chair's partners, financial and human resources, and the technical progress made in modeling.

Graph 1 shows a timeline of the projects as they stand today. It clearly shows the significance of the period at the end of 2015, which involves gathering prospective material to prepare COP 21 in Paris.

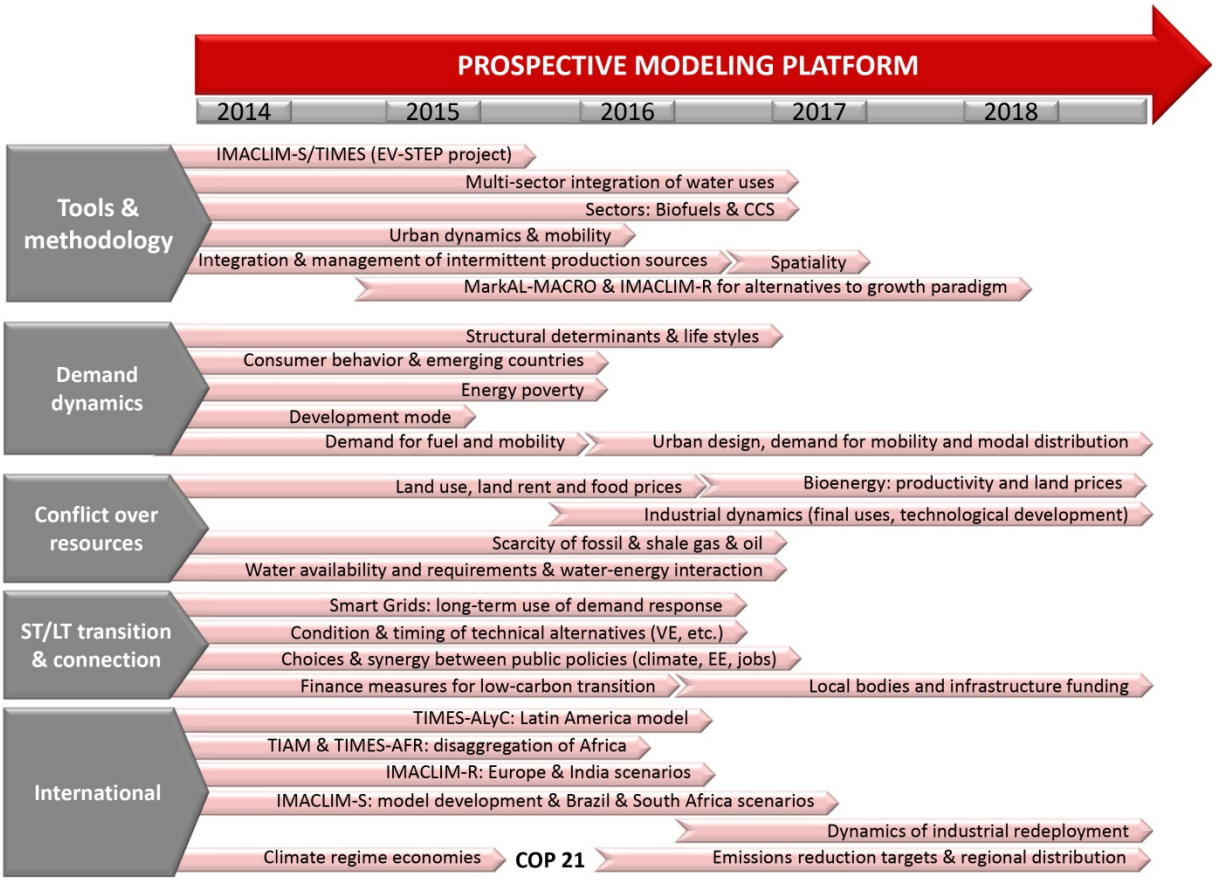

Figure 1. Timeline showing the MPDD Chair's anticipated projects from 2014-2018

I. CONSOLIDATE THE PLATFORM FOR PROSPECTIVE TOOLS

The main vocation of the MPDD Chair is to build numerical tools capable of producing coherent images of the future and transition pathways to these images in order to inform decision-makers in the public and private sectors about the mid-, long- and very long-term consequences of decisions made today. At the heart of the measure is the connection between optimization models and hybrid general equilibrium models. Its objective is to ensure (i) dialogue between engineering and economic approaches, (ii) consideration of the interfaces between the energy sector, other sectors of activity concerned by sustainable development issues, and macroeconomic dynamics, and (iii) the capacity to work at several geographic levels and reconcile different times scales.

Building up the capacity for dialogue between engineering and economic models will work in two directions: (i) a new wave of 'hybrid' accounting matrix construction, ensuring compatibility between social accounting, energy balances, physical indicators of activity and data on income distribution; (ii) use of the range of regional TIMES versions and the potential of the macro linkage MarkAl-MACRO and IMACLIM-S/Nexus, in particular after finalizing the TIAM – IMACLIM-S coupling for Europe.

Developing interfaces between energy and other domains of activity will center on:

- Integrating choices on water usage in several sectors (energy, industry, agriculture) to explore the resulting conflicts, and the ways in which climate change is likely to exacerbate them;
- More detailed analysis in models of biofuels and carbon capture and storage (CCS) technologies in order to identify the constraints to employing these technical methods at several scales, and examine how the allocation of a growing amount of land for non-food usage impacts on land and food prices;
- Integrating urban dynamics (urban area models and models of city systems) to understand how mobility requirements develop, the technical coherence between urban design and transport mode choices and *in fine* the demand for standard fuel. The challenge is, in addition to considering energy, property and work markets in the same framework, to explicitly introduce transport infrastructures and their impact on spatial dynamics at inter- and intra-urban scale and international scale;
- Developing a minimal representation of i) financial circuits to integrate capital flows and shortfalls between the constitution of savings and their reinvestment in industrial activities and infrastructures and ii) state debts to take into account constraints on public funding.

The spatialization and connection of time scales will aim to understand the implications of policies that necessarily act at several levels, from global to local, and the impact of different kinds of phenomena. This integration nevertheless brings up significant methodological obstacles that we will tackle via three main themes:

i) Modeling networks to manage intermittent electricity production sources [cf. section II] by reconciling short- and long-term approaches and spatial scales;

ii) The consideration of transport facilities and land heterogeneity [cf. supra];

iii) “Downscaling” global general equilibrium models to national-scale equilibrium models [cf. infra].

These three methodological projects will be led by two Chair teams working with other prospective modeling teams as part of the coordination platform described in section III.

II. FOUR STRUCTURING PROGRAMS

The MPDD Chair will develop programs along four main lines: (A) Demand dynamics: from usage to consumer behavior; (B) Energy resource conflicts and alternative supplies; (C) Transition management and short-term/long-term connections; and (D) International background to sustainable development policies.

A. Demand dynamics: from usage to consumer behavior

A1. Determinants of household consumer behavior

The continuation of the work initiated by CIRED and CMA on modeling behavior in residential sectors and transport will include studying the connections between consumer dynamics and sustainable development issues:

- By researching the specific role of changes in the structure of usage in energy demand dynamics, in parallel with an analysis of factors like GDP growth, demographic structure and energy efficiency. The evolution of the structure of usages will be linked to the *structural determinants of demand for energy services,* in other words the structure of the production apparatus and *evolving lifestyles*;
- By analyzing the influence in global scenarios of hypotheses on *emerging countries' mimicry of consumer behavior* (e.g. electricity, housing, mobility, diet) on different levels of direct or indirect carbon emissions (including those related to agricultural expansion);
- By identifying *potential bifurcations in consumer behavior* in terms of electricity, mobility and diet, in particular by making a retrospective, prospective study comparing developed and emerging countries (France and Brazil).

A.2. Fuel poverty and essential needs

This research operation will center on the determinants of fuel poverty that are not strictly linked to income (e.g. geographic location, quality of equipment). It will be based on the program to hybridize social accounting matrices (cf. I supra) to incorporate available surveys of households (France, Brazil, South Africa) and identify which households are subject to fuel poverty. This will allow a prospective evaluation of the fuel poverty situations, on different time horizons, of the mechanisms that lead to their reproduction. We will associate approaches based on an original classification of household consumption resulting from crossing their energy consumption for transport/residential usages: this will help us understand the impacts of the carbon constraint on households, the negative effects, and the public policies likely to avert them. The current geographic extension of this research will depend on both the resources mobilized and exchanges with partners.

These analyses will be consolidated at global scale, at a lower level of granularity in prospective exercises on essential needs, to show, in the different regions of the world, the mechanisms that lead to a reproduction of or exit from poverty situations.

A.3. Energy demand and the dynamics of mobility requirements

Progress continues in modeling the links between (i) spatial and mobility dynamics on "city system" models, at international scale, of a country (France) and on models of built-up areas (Île-de-

France, PACA, Bologne, Mumbai), and (ii) making transport facilities endogenous (cf. section I supra). The aim is to gain a better understanding of the dynamics of mobility requirements in terms of volume and modal split. We will then be able to integrate (i) the costs of switching, property markets and mobility requirements, (ii) the relative efficiency of alternative (or soft) transport modes, in particular electric vehicles, and (iii) the transport content of production (just in time, geographic dispersal of channels).

The first objective will be to revise existing scenarios in terms of fuel demand on a global scale (twelve major regions) and show what determines bifurcations in the mobility content of growth. The second objective will aim to carry out the same type of work in a European context to analyze the sustainability of the current "peak" in fuel consumption. Lastly, we will undertake a program, whose precise content and geographic area will be defined in liaison with the partners, on the connections between urban design, mobility demand and modal assignment between "soft" modes, electric vehicles and standard fuel vehicles.

A.4. Determinants of demand from industrial sectors

To understand the demand dynamics of the industrial sector (in quantity and structure), we will put together a prospective study of final uses considering technological progress in energy-intensive sectors and, thanks to a better description of channels and value chains in these sectors, we will achieve a better representation of the dynamics of industrial restructuring on an international scale (type of specialization, transport, etc.). We could also envisage how some solutions (e.g. energy efficiency, smart grids, smart cities, CCS) would be compatible with carbon-reduction policies. This program could be carried out after discussion with partners at different levels of sectoral disaggregation and could principally concern major energy-intensive sectors (e.g. cement, steel, petrochemicals).

B. Energy resource conflicts and alternative supplies

B.1. Non-conventional fossil fuels: shale oil and gas

The prospective exercises carried out here aim to clarify the debate on the scarcity of resources ("peak oil") and the evolution of energy prices. This long-established theme with relatively stable terms needs to be looked at anew in the context of the controversies surrounding shale oil and gas. Existing modeling apparatus will be improved to integrate the determinants of new investments in fossil fuels (coal, gas and oil), including shale oil and gas on one side, and carbon capture and storage procedures on the other. Thus we can rework existing energy scenarios by studying the links between fossil fuel markets and transformations in global geopolitics, and the climate polices implied by diverse visions of the future of hydrocarbons from shale. Exercises will highlight the sources of instability in global fossil fuel prices, fuel price differences between regions and their implications for Europe.

B.2. Bioenergy and land use

The development of bioenergy, especially biofuel, will be studied by consistently integrating, at global scale, hypotheses regarding the availability of land, the farming resources mobilized, the technical choices (mechanization, use of fertilizer, irrigation), and the relative productivity of work in agriculture and other sectors. The aim is to verify whether or not existing energy scenarios are too optimistic regarding the role of biomass (including biological storage), in ignoring the repercussions of constraints on land, food and water prices, as well as relative changes in labor costs between agricultural and non-agricultural work.

B.3 Remove the hurdles to extensive use of intermittent resources

The project to use intermittent resources on an extensive scale will be considered in terms of the technical plausibility of the resulting electricity system. The choice of technological avenue can also be looked at in terms of electricity supply reliability. In particular, a breakdown of the quantitative indicators can be used to assess the reliability of an electricity production mix and thus consider under what conditions of (i) transforming the electricity network (centralized/decentralized), (ii) employing storage technologies, and (iii) implementing intelligent solutions (demand response), the massive integration of intermittence in electricity systems can be envisaged.

B.4 Water conflict and multi-sectoral implications

The objective is to integrate water availability into technological and integrated models in order to explore water conflict in several sectors (energy, industry and agriculture), and the ways in which climate change is likely to exacerbate it. Prospective exercises on energy issues give little or no room to interactions between water and energy and specific regional factors. However, it is indispensible to use these two-directional interactions to ascertain the optimal “water-energy” mix based on different, not necessarily exclusive, assertions (economic, social, environmental).

C. Transition management and short-term/long-term connections

Although multiple scenarios currently exist to shed light on the conditions of an energy transition under environmental constraint, analysis is lacking as to the economic, technological and social conditions for triggering this transition. We will therefore work on developing tools on short-term/long-term connections to better understand the policy mixes required to redirect technical systems and development modes.

C.1 Conditions and timing for employing technological options:

Energy and climate policies are framed by a vision of the transformation of technical systems accompanied by an optimal timetable for employing technologies in decreasing order of merit. This can be misleading when we introduce the internal coherences of the energy system at a technical level and the resulting inertia, the technological hurdles to overcome, the endogenous lessons to learn, and the macroeconomic costs of support policies. Thus, this framework makes it difficult to go

beyond opposing theses, one of which argues that renewable energy should only be used when it is competitive, while the other centers on ambitious short- and mid-term targets to bring down the cost of this energy by playing on the technical and institutional learning process. To further its research into gaining a pertinent technological understanding, the MPDD Chair will attempt to highlight the potential of smart grids, employing Demand Response over the long term and, symmetrically, identify the technical, economic and institutional obstacles, paying special attention to the flexibility constraints of the electricity system. A particular focus will be put on the use of electric vehicles, especially in the continuation of the work already started at European scale (cf. section 1).

C.2. Choice and synergy between public policies

Over and above the debate on the "double dividend" of tax reforms based on carbon tax, climate and energy policies are generally analyzed without explicitly integrating their connection to other public objectives. The Chair will try to make up for this gap by developing programs in three directions:

- The consistency of policies on energy saving and energy efficiency with decarbonization targets (3x20, the 2050 EU roadmap). This will center on highlighting the counter-productive effects of a combination of instruments in terms of the technical efficiency of systems and from an economic point of view;
- The evaluation of environmental policies in terms of their impact on employment, welfare funding, industrial competitiveness and income distribution. This leads to a systematic study of the public policy combinations that can extend the zones of compromise between targets (carbon tax, land tax, property prices, infrastructure policies);
- The contradictions and potential synergy between climate policies and European energy policies, in particular the extension of market mechanisms that, in the absence of capacity markets, are a source of uncertainty for long-term investments. We will also look at the consistency of policies in terms of their efficiency to constitute industrial channels and disseminate the expertise needed to adapt technical solutions to local conditions.

In particular, the accent will be on the obstacles to change constituted by constraints to reconverting activities on various sectoral and geographic scales and the presence or absence of a sufficient network of activities for local economic adaptations to take place without a significant impact on jobs.

C.3. Financing the energy and ecological transition

This operation aims to introduce financial constraints and capital flows into prospective scenarios which, since they do not currently represent the issues of financing in a context of uncertainty, do not make a contribution to understanding one of the major shortfalls of public policies based only on price signals.

The objective here will be to (i) introduce risk into investment behavior, (ii) study measures to create carbon assets and certificates, based on the conventional fixing of a social cost of carbon that would mobilize the banking system and private savings managers, and (iii) evaluate the short- and

mid-term macroeconomic impacts on growth, competitiveness and debt reduction of activating this financial leverage effect and implementing a monetary easing policy that relies on carbon value.

This problem will be tackled according to the sector concerned and the scale of intervention, integrating the connection between stakeholders at local and regional scales, national policies and international funding. One of the priority fields of application in 2014 and 2015 will be to explore financing measures for the low-carbon transition in a financial crisis context likely to launch the quest for an international protocol to follow on from the Kyoto Protocol and prepare for COP21 scheduled to take place in Paris. Other studies will be carried out to introduce for example the role of local bodies (towns, regions) into the funding of low-carbon infrastructures. The precise content and geographic scale of these studies will be discussed with the Chair's partners, integrating the initial experience of this research program.

D. International context of sustainable development policies

As in the past, the MPDD Chair will have a strong international dimension. This will be developed in two directions: the first is to produce scenarios to analyze the various global governance proposals regarding climate; the second is to carry out region-focused analyses, mostly in liaison with teams from developing countries.

D.1. Global scenarios and climate governance 2015-2020

The objective of this research operation is to analyze:

- The technical and economic conditions of the different climate stabilization targets, in particular the 2°C objective and emissions profiles leading to an overshoot or higher stabilization levels;
- Combinations of instruments (taxes, carbon markets, infrastructure policies, sectoral agreements, carbon finance macroeconomic policies) that trigger 'low-carbon' investment choices (cf. C3) while evening out transition costs;
- The potential of an agreement on a 'social cost of carbon' and the creation of carbon assets likely to circumvent these difficulties in the face of the deadlocks of the 'burden sharing' mentality that dominated post-Kyoto, to resolve climate/development issues based on the experience of operations A.2 and C.3.

This operation will be strongly influenced by the production of material for COP21, to be held in Paris in late 2015. The Chair will increase its involvement in international networks centered on expertise/decision-making (EMF, IAMC). It will continue to organize side events at Conferences of the Parties and increase its contributions to the LCS-RNet network, which comprises the G8 and major emerging countries.

D.2. Region-focused analyses

The Chair's two teams have established a sufficiently solid international position to develop national and regional-scale prospective studies in liaison with competent teams from the countries and regions concerned:

- Production of energy/economy/climate scenarios for South Africa, Brazil and South America, and India;
- Analysis of the connections between emissions reduction/growth and inequality in Brazil;
- Study of local energy challenges associating geopolitical constraints, networks, and resources in Africa;
- Impacts on energy policies of issues linked to the availability of water resources in the Middle East;
- Evaluation of the reliability of large-scale electricity production based on renewable intermittent resources in the United States;
- Evaluation of the energy security challenges facing Europe in 2050.

III. ACTIVE INVOLVEMENT IN THE SCIENTIFIC COMMUNITY AND EDUCATION

The success of the event "Journées de la Chaire" show that, in contrast to 2008, the MPDD Chair's 'brand identity' is now solidly established in academic, expertise and decision-making spheres. Building on this reputation, the Chair will develop two types of initiative:

- Organize ***scientific seminars*** open to national and international teams involved in different sectors of activity (energy, transport, agriculture, etc.) or in methodological aspects judged as critical (coupling, databases, calibration, uncertainty treatment, numerical methods). This work could involve joint productions with a broader scope than the two laboratories that make up the Chair.
- Organize ***closed seminars on strategic exploration*** involving partners to analyze the results of prospective modeling on themes esteemed as strategic, following Chatham House Rules.

This measure in no way prevents the Chair from making a more vocal contribution to public debate by taking the initiative on important points independently from the political agenda. This could involve, for example, organizing exchanges with other modeling teams on the energy transition in France, in a way that avoids contradicting the validation of research in scientific journals. These events will be discussed and scheduled with the Chair's partners.

Lastly, the Chair will continue and boost its contribution to ***education on research and through research***. This will mostly be done through extending the existing ***Energy Systems Optimization (OSE) Specialized Master's Degree*** run by the CMA, by creating within the ***Environmental Economics, Sustainable Development and Energy (EDDEE) Master's Degree*** (common to Ecole Polytechnique, Ecole des Ponts Paristech, MINES Paristech, AgroParistech, Paris Ouest, INSTN and EHESS) a top-level prospective modeling course for 10 to 15 students per year from the leading French universities. This course will be organized by CIRED for the academic year starting

in 2014. Lessons, internships and research papers will play on complementary factors with the OSE specialized Master's Degree, with systematic cross-fertilization of ideas in the two laboratories.

The EDDEE + OSE courses will provide the Chair with a ***hotbed of expertise***, with the potential to identify talented students and thesis subjects of interest.