Energy simulations at community levels; a new methodological approach for a new model

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ABSTRACT

Nowadays, considering the overall framework related to rational use of energy and environmental problems, urban districts and communities could represent an optimal scale for the implementation of promising energy strategies including local renewable energies use, distributed generation, micro-cogeneration and multi-generation. However, a part some particularly lucky cases, community energy systems are very obsolescent, not efficient and fossil dependent. To that end it is very important to provide reliable models and applications in order to improve energy systems limiting the risk of dangerous errors and difficultly predictable negative effects.
Present work was preceded by a survey about existing sustainable and energy efficient communities, about promising technologies for improving district energy system and about simulation models for the evaluation of the energy and environmental performance of communities. While this part introduces also a new simulation model able to evaluate electric and thermal energy demands, power and thermal generation and useful indicators referring to energy, renewables valorisation, exergy, entropy, CO_2 emissions and cost effectiveness. We hope that our research could represent a relevant contribution to develop tools for supporting and redirecting energy systems decisions and choices, taking into account the importance to act on three sides of the energy system: reducing energy demand; optimizing generation systems and implementing advanced management control systems.

1. INTRODUCTION

Climate change, environmental pollution and resource depletion are issues that have to be addressed in global sustainability reasoning. The increasingly complexity of contemporary society has determined a stronger interconnection between human activities, energy use and pollution reduction strategies. For this reason scientific knowledge and information need to overcome the narrow subdivision of academic fields of study toward a multidisciplinary collaborative research focused on energy sustainability and environmental impact mitigation. This is a challenging task in particular for contemporary cities, where increasing demand for energy services is combined with rapidly changing lifestyles and habits. A large part of urban systems research in the last years has focused on the development of computational tools to enable efficient data analysis and process modelling (White and Engelen 2000). Models have been developed to address the great variety of processes that happens in cities and process has become a more common technique for analyzing trade-offs between solutions in problem solving. In the field of computer science, much progress has been done in the development of standards, protocols and infrastructures for information interchange and distributed computing. Today the possibility to store and aggregate large amount of data and handling time-consuming computational processes with relatively inexpensive hardware and software makes it possible to think of a smarter use of available technologies and efficient control of energy consumption at the community level, both to reduce energy demand and environmental impact of energy services. As described in Caputo and Costa 2009, energy systems based on distributed generation (DG) could represent a relevant improvement both in demand and supply side. Beyond efficiency and carbon reduction, DG technologies may ensure a better reliability for users that require uninterrupted service and can contribute to deferring transmission upgrades and expansions at a time when investment in such facilities remains constrained. Security of supply is an important issue too.

Main strengths of DG can be summarized as follows:

1. production from different distributed energy sources together with the possibility of exploiting local renewable sources with benefits in term of decreasing of fossil energy needs and protection against black out (lower risk than in case of concentrated generation);
2. possibility of involvement of end users in reducing energy demand and peak power and in optimizing primary energy consumption;
3. possibility of manage energy generation, conversion, storage and transportation respecting the evolution of the energy demand and matching optimal energy demand mix as results of optimal combination of functions of the built environment;
4. combined heat and power technologies enable the correct use of thermal energy that would normally be wasted, and determine a reduction in primary energy use and carbon emission.

2. METHODS

For studying a community energy, it is very important to have reliable data about energy final uses and supply system.

In our contexts, it is very hard to accomplish this step, also because of the energy liberalization that pushes electricity exchange also at international level in order to maximize financial profits.

More transparency is needed in order to implement correct analysis and models.

Giving for granted the features of a present energy system, the paradigm shift in energy systems has to be supported by mandatory regulations, technological infrastructures, business strategies, education, etc to be effective. In this context, local energy policy involves, necessarily, the planning and the design of efficient districts and solution tailored to meet specific needs. Integrated energy systems (Bilodeau and Agbossou 2006), characterized by efficient use of renewable energy sources and fossil fuels within a polygeneration framework, are a promising solution for urban districts where a sufficient spatial energy intensity justifies investments in active grids, district heating and district cooling networks.

The correct design of technical solution needs a better understanding of the dynamic interaction between energy demand by the customers, energy distribution systems, distributed generation and storage technologies. The implementation of models to simulate and optimize the dynamic behaviour of energy districts is today the goal of many research (Larsen et al. 2004). Energy loads represent the basis for distributed generation technologies sizing and dispatch optimization, within a simulation and optimization procedure. Dynamic simulation of energy loads for a district is more complex than a single use simulation and need to integrate available computational models, statistical data and soft computing techniques (Metaxiotis et al. 2003).

Furthermore in existing urban districts, generally, there is the need to deal with uncertain and frequently incomplete or noisy data which complicate the robust optimal solutions research (Nemirowsky et al. 2009) with respect to varying boundary conditions. The correct simplification of the analysis is clearly an important factor to provide useful methods and models in real world application.

To that end, a new methodology will be described, taking into account the capabilities of available district models and promoting actions related to demand side, supply side and management.

2.1 *Demand side and demand response management*

Energy demand management, or demand side management (DSM), involves actions that affect the pattern and quantity of energy demand by the end-user. Reducing building heating and cooling demands through good practices, reducing electricity demand via more efficient electric appliances, increasing land-use mixes and densities to reduce commuting and travel requirements, minimizing infrastructures and optimizing their operation to reduce embodied energy and life-cycle energy consumption are some examples of how we can reduce energy intensity while maintaining an adequate standard of living. On the other hand, in the emerging DG paradigma, the maximization of on-site renewable energy resources use and the adoption of adequate technologies and practices, to reduce dependence from national grid delivered electricity and fossil fuels creates a stronger connection between energy demand and supply system. This requires the correct design of specific technical solutions and the management of demand in response to varying supply condition, in particular where high penetration of variables during time is present. This is an already well known concept in electric systems, where demand response management (DRM) is applied to reduce load in peak hours and in response to real-time market prices, but can be successfully interpreted as a more wide and general concept (involving other types of load) when applied to local energy systems control (Collazos et al. 2009).

2.2 *Distributed generation and management*

The evolution of electric infrastructures towards micro and smart grids will led to a more effective integration of stochastic energy sources (renewables and waste heat) into power system. The combination of load curtailment and rescheduling strategies with on-site additional generation capacity and distributed storage systems, enabled by standard communication protocols over the grid, will result in a better exploitation depending on meteorological conditions energy sources such as wind and solar. As described in the previous paragraph, in general today customers do not face short-term electric energy production cost and thus have only little incentives to reduce demand in peaking conditions. Since costs in peaking hours can be substantially higher customers will reduce their demand if real-time pricing is adopted. On the other hand, the interaction of distributed integrated energy systems and present large centralized power plants could result in interesting economies of scale and environmental benefits (Pepermans et al. 2005). By avoiding the costs of additional capacity and infrastructures (generation plant, transmission lines and distribution lines cost) utilities will save capital-intensive investments for peaking supply conditions, which represents, from an economic point of view, expensive assets not properly used. Furthermore small scale generation plants can adapt better and faster to load curve variation than large ones. Finally, DG will result in reduced investments in operation reserve, improved reliability by controlling extreme conditions and better rates of return due to an improved capacity factor of the whole generation and distribution system.

Recent research contributions to the paradigm shift towards DG are presented and the main differences among them are highlighted referring to: microgrids (Hatziargyriou et al. 2007), virtual power plants (Pudjianto et al. 2007), integrated energy systems (Zaltash et al. 2006), intelligent power grids (Coll-Mayor et al. 2007) and Energy Hubs (Geidl et al. 2007).

Future energy systems will probably own some of the key features of the previously described visions: it is not clear, up to now, if a specific vision will prevail over others.

Anyway, in the EU, the path towards future energy systems has been clearly set with many directives and research initiatives. Furthermore recent developments in international and EU standards like EN 15900:2010 and EN 16001:2009 confirm this trend.

For these reasons methods and models for distributed generation systems planning and design take into account the key features of the presented emerging paradigma, summarized in table 1.

Table 1. Vision of future energy systems – Features and concepts.

Feature	Concept
Integrated	Integration between different energy sources, generation technologies and ICT
Interactive	Interaction between customers and markets ("internet model")
Optimized	Optimization of economic performance, energy performance, environmental performance, reliability and availability
Resilient	Resilience with respect to disruptions and attacks
Adaptive	Adaptation to rapidly changing conditions
Predictive	Prediction of loads, RES production, market trading, possible outages and planning maintenance scheduling based on operational data

3. RESULTS: TOOLS FOR DG PROJECTS

As mentioned before, our research includes a survey of tools for simulations and designs able to model energy scenarios at the community level taking into account economic, energy and environmental performances. Among them, some has been selected and analyzed; their classification and synthetic description are reported in table 2 and in the following paragraphs.
Further, as results of the research, a new methodology for developing a more suitable tools is described in the following.

Table 2. Distributed generation tools analyzed.

Category	Tool	Description
Accounting tools	RETScreen	Platform for the evaluation of renewable energy technology implementation
	LEAP	Energy policy analysis model
Simulation tools	HOMER	Simulation and optimization model for DG systems
	TRNSYS	Transient system simulation program
	HYDROGEMS	Library of models for integrated hydrogen systems based on renewable energy analysis
	TESS	Library of models for thermal systems analysis
	STEC	Library of models for solar thermal electric systems simulation
	TRNOPT/GENOPT	Optimization software
	EnergyPlus	Whole building energy simulation model
Optimization tools	EnergyPLAN	**Energy systems analysis model**
	DER-CAM	Optimization model for DG systems
	DEECO	Energy systems modeling environment
Externalities and environmental impact calculation tools	Externe	Externalities calculation methodology
	Ecosense	Integrated environmental impact assessment model
	AERMOD	Pollutant dispersion model
	GEMIS	Integrated systems analysis model
Databases	CO2DB	Database for carbon mitigation technologies
Advanced local energy planning tools	PLACE^{3}S	Local energy planning methodology
	LEED for Neighborhood Development	Guidelines and rating system for sustainable **neighborhood design**
Tools under development	XEONA	Object oriented DG simulation environment
	H2RES	DG simulation model for islands and isolated regions
	ODESSE	Simulation and optimization model for energy efficient building design

3.1 Geographical information systems

Geographical Information Systems (GIS) are today commonly used tools in urban and regional scale planning. For this reason, a stronger connection between energy and environmental models and urban planning tools is a key factor for the development of sustainable communities (Medrano et al. 2008). The interoperability and interchange of data between computational tools and information systems are essential. As stated before, high efficiency districts require tailored solutions and thus a GIS is necessary to ensure realistic basis, by planning interventions in a reliable and affordable way and by enabling faster and accurate calculations on a spatial base. GIS tools are useful in DG projects for identifying potential sites by calculating spatial energy intensity and providing necessary statistics.

3.2 Energy accounting, simulation and optimization

As stated before, the analysis of energy, economic and environmental performances of solutions and scenarios dealing with DG adoption in the urban environment is a process that articulates into various phases. Energy accounting, simulation and optimization tools are presented in the following paragraphs.

3.2.1 Energy accounting tools

Energy accounting tools are models designed for the estimation of key parameters and the calculation of quantities in energy efficiency and renewable energy projects. In this field, RETScreen International Clean Energy Project Analysis Software is an excel-based platform for the evaluation of energy production, lifecycle costs and greenhouse gas emission reductions for various types of renewable energy technologies and energy efficiency measures. This software includes product cost and weather databases. Available modules are wind energy, small hydro, solar photovoltaic (PV), combined heat and power (reciprocating engines, fuel cells, gas turbine, steam turbine), combined heat, cooling and power, biomass heating, solar air heating, solar water heating, passive solar heating, ground-source heat pumps and others. Weather data, resources availability, efficiencies and capital cost of energy conversion technologies, O&M costs and emission factors are also provided in a database format. Output results are energy production, life cycle cost, pollutant emissions, risk analysis and financial analysis. This platform can be easily employed for the evaluation of the techno-economic feasibility of a local single clean energy technology implementation.
In the field of integrated scenario-based energy modelling tools, LEAP (Long range Energy Alternatives Planning) is a comprehensive energy accounting model developed by SEI (Stockholm Environment Institute). Its scenarios (Pandey 2002) account for how energy is consumed, converted and produced in a given region under a range of alternative assumptions on population, economic development, technology, price, etc. It supports a range of simulation methods for modelling both capacity expansion and plant dispatch strategies. The model includes a built-in Technology and Environmental Database (TED) containing data on costs, performance and emission factors of various technologies. LEAP can be used to produce energy scenarios and emission profiles also for a specific sector (e.g. from cement production, land-use change, solid waste, etc.). This model can be employed for accounting, sensitivity and parametric analysis of energy scenario for a region, but can also be used for local energy planning in cities due to integrated energy and environmental analysis capabilities.

3.2.2 Simulation tools

Simulation models are tools developed to evaluate the adoption of DG technologies from a dynamic perspective. They generally employ the use of numerical techniques to perform transient analysis. In this field HOMER is a computer model developed by US National Renewable Energy Laboratory that simplifies the task of evaluating design options for both off-grid and grid-connected DG applications. Optimization and sensitivity analysis algorithms are used to evaluate the economic and technical feasibility of technology options and to account for variations in technology costs and energy resources availability. Output results are optimization and sensitivity analysis of the system involving energy production, fuel consumption, emissions and costs. This model can be employed for the evaluation of the techno-economic feasibility of a local DG system project under constraints. Although it is not a real transient simulation program, it can provide useful insights on the dynamic behaviour of a DG system.

In the field of detailed simulation tools, a comprehensive environment is TRNSYS (Transient System Simulation), which elements are computational modules developed for the transient simulation of different technologies. Libraries such as HYDROGEMS (Corsini et al. 2006), included as a standard from version 16 of TRNSYS software, TESS (Trcka et al. 2006) and STEC (Garcia et al. 2008) are available for the simulation of hybrid integrated energy systems. As introduced before, input data in transient simulation are parameters and technical specifications of system components, weather data and loads data. In general design parameters are set inside the simulation assembly, but they can also be read from external files through specific applications. Because of its characteristics, TRNSYS simulation environment is well suited for use in research and development field. Additionally it can be coupled with GENOPT, generic optimization software developed at Berkeley Lab, via TRNOPT module. In this way, it is possible to combine the simulation capabilities of this flexible environment with optimization algorithms. This is fundamental to avoid a trial-and-error procedure that can become particularly time-consuming and error-prone when dealing with complex systems analysis. Additionally, optimizers can help in a more scientific and rational exploration of alternative that otherwise would not be possible. Similarly, this strategy can be employed also with the whole building energy simulation model EnergyPlus (Hartkopf 2004), developed by the US Department of Energy. EnergyPlus can calculate heating, cooling, lighting, ventilating and other energy flows within a building. Its capabilities comprise the detailed simulation of HVAC systems, distributed generation systems, thermal comfort calculation and water use calculation. Generation technologies that can be modelled include PV, solar thermal, microturbines, gas turbines, reciprocating engines, fuel cells and general microcogeneration systems.

In the design of energy efficient districts, EnergyPlus and GENOPT can be used in combination to optimize energy demand and interaction with electric grid and local district heating and cooling networks.

3.2.3 Optimization tools

The recent development of multiobjective optimization techniques offers an important contribution towards the development of models to determine solutions that represent the best compromise between several conflicting goals.

In this context, EnergyPLAN is a software model for energy system analysis (Lund 2005). This model performs a techno-economic analysis of the consequences of different energy investments and designs suitable energy planning strategies in relation to availability of distributed energy resources, technical regulations and economic optimization. Output results are energy production, costs and emissions for the selected strategy. This tool can be employed for feasibility evaluation of large scale DG system projects, but also for the analysis of DG in urban energy districts.

Another techno-economic optimization model, more strictly related to DG adoption within buildings and microgrids, is DER-CAM (Distributed Energy Resources Customer Adoption Model). This is an economic model of customer distributed energy resources adoption, written as a mixed-integer linear programming and implemented in GAMS (General Algebraic Modelling System) language (Siddiqui et al. 2005). The scope behind this model is the determination of the lowest-cost combination of distributed generation technologies that a specific customer can install, the appropriate level of

capacity and the correct dispatch strategy to minimize global annualized cost and total energy bill. DER-CAM is mainly an economic model that can be employed in the evaluation of DG installation by the end user and within a micro-grid (Maribu et al. 2007).Input data are electrical and thermal load curves with one hour resolution, technical features of conversion technologies, electric energy and natural gas tariffs, initial investment capital, operation and maintenance costs and interest rate of the investment. Output results are optimal plant size and technologies, dispatch strategy and cost of produced energy. This model can be employed for determining both techno-economic and dispatch optimization of distributed generation systems.
To conclude, Deeco (Bruckner et al. 2005) is an energy systems simulation-optimization environment developed at IEE (Institute for Energy Engineering) of the Technical University of Berlin. It is used to define, guide, and evaluate sustainability improvements related to DG technologies and energy efficiency measures: typical goals are CO_2 and fossil fuel dependence reduction. Improvements can be classified as hard, for instance, such as enhanced plant performance or revised connectivity, or soft, such as targeted demand modification or amended operational policy. It represents a given system as a network of plants whose state evolves dynamically over time. Deeco determines best practice operation as defined by the selected management objective, using recursive dynamic optimization techniques. As stated before, it is generally used to compute sustainability gains versus financial cost relative to the introduction of more efficient technologies with respect to business-as-usual strategies. Input data are electrical and thermal load curves with one hour resolution, weather data and energy sources availability data, technology efficiencies and features, O&M costs, emissions constraints and optimization strategy. Output results are energy production, emissions and costs of the energy system. This model can be employed for the evaluation of technical solutions and energy policies within urban districts in an optimization perspective.

3.3 Environmental impact calculation in the framework of local energy planning

As introduced in before, local and global impacts of proposed solutions have to be calculated when addressing environmental responsible local energy policies. In the subsequent paragraphs useful tools for environmental impact calculation are presented. Local air quality and noise levels are certainly the most important aspects to be considered for their direct implications in urban DG projects. However, in general, a life cycle assessment approach for all technologies, practices and supply chains is necessary to evaluate the sustainability of the proposed solutions. These aspects belong to the fifth analysis phase, as described in the introduction of this chapter.
Additionally advanced local energy planning is a critical issue when dealing with DG implementation. Energy efficiency measures and DG technologies adoption directly reflect on local environmental quality, and their effects must be clearly identified. Furthermore, at the community level, direct and indirect energy use has to be properly taken into account in urban planning and regulations.

3.3.1 Externalities and environmental impact calculation tools

Externalities minimization is a fundamental goal to ensure sustainability in energy systems. In this field, Externe (Schleisner 2000) is a research project whose purpose is to enable is to define a systematic approach for the monetary evaluation of the external costs of various technologies and energy services, in particular electricity. Externe has become a very diffuse reference in the last years. The computational model is a classical “bottom-up” approach, in which the analysis is conducted by going up to the causes, through impact pathways. The main work phases of this methodology are: characterization of the problem (determination of pollutants’ types and flow), evaluation of the issues (pollutant dispersion calculation), determination of pollutants concentration effects (effects on receptors), calculation of impacts and relative costs (external costs).

A software package called EcoSense (Genon and Brizio 2005) is needed to enable Externe methodology application. In general, depending on the question to be answered, all stages of the life cycle of a technology (e.g. construction, dismantling, transport of materials and fuels, fuel life cycle) can be considered. EcoSense provides harmonized air quality and impact assessment models together with a database containing relevant input data for European countries[1].

Pollutant dispersion models are necessary to enable the calculation of environmental effects of energy services and the subsequent calculation of external costs. A widely used model for local pollutants dispersion calculations is AERMOD (Cimorelli et al. 2005). It is a steady-state plume model that incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts, including treatment of both surface and elevated sources, and both simple and complex terrain. This model is actually composed of three different computational modules: AERMAP (ground data pre-processor), AERMET (meteorological data pre-processor), and AERMOD (dispersion calculation). The final output is pollutant concentration to the receptors (the places where the population is present, typically buildings; the maximum concentration of pollutants to the receptors can be calculated by considering different atmospheric conditions.

On the other hand, the paradigm shift at the community level requires the introduction of newly developed technologies, products and technical upgrade of existing ones. However, the energy and environmental superiority of one solution over competing ones has to be proved through whole life cycle assessment and environmental impacts. This is not a trivial task and more research works must be done in the field on dynamic LCA (Pehnt 2006) especially in the perspective of rapidly increasing penetration of renewable energy sources. The integration of life cycle assessment tools in community scale projects is today necessary to ensure sustainability of solutions.

A global environmental impact calculation tool is GEMIS (Global Emission Model for Integrated Systems) developed by Öko-Institut (Madlener and Stagl 2005). GEMIS performs full life-cycle computations for a variety of fuel chains, calculating emissions, resource use and costs. The internal database offers information on fuel chains and different technologies. Inputs are energy, materials, processes and transport system data. Data can be taken from an external information system or modeled inside and calculated. Outputs are energy consumption, emissions and costs of the whole life cycle. Flows and stocks can be evaluated using performance indicators. This model can be employed for the evaluation of global environmental impact of policies and technical solutions.

3.3.2 Databases

The evaluation of economic and environmental effects of energy policies requires several data. In this sense, specifically designed databases play an important role. An example in this field is CO2DB, a database for collecting and analyzing detailed data on carbon mitigation technologies developed by IIASA (International Institute for Applied Systems Analysis). This database contains approximately 3000 technologies, including detailed technical, economic and environmental characteristics as well as data on innovation, commercialization and diffusion. Users can easily compare CO2DB's data according to any of the technology characteristics included in each database field (Riahi et al. 2004). It is also possible to make energy chain calculations as well as comparison tables and graphics on the technology and on the chain level. This tool can be therefore employed for collecting, organizing and using data for projects in the field of mitigation strategies for the energy services sector. Additionally, life cycle inventory data from business associations and research institutions are given at for materials, energy carriers, transport, and waste management.

[1] In any case data must be carefully evaluated with respect to specific conditions which are present in the project

3.3.3 Advanced local energy planning tools

In this field PLACE3S is an energy-based planning methodology that integrates public participation, community development and spatial analysis within a geographical information system framework. The scope behind this methodology is to help public administrations creating local economic development, job opportunities, while reducing at the same time environmental impact of energy services and fossil resources use. A great importance in the model is given also to mobility and suburban sprawl problem. The implementation of community programs in this case is supported by GIS tool, through a step by step results monitoring. Sustainable energy use and environmental impact mitigation involves several aspects: reduction of traffic congestion, improvement in outdoor air quality and internal environmental quality of buildings, reduction of costs for infrastructures, preservation of landscape and wildlife, promotion of local economic development and job opportunities. Model inputs are demography data, industrial, residential and tertiary energy consumption data, type of industrial and tertiary activities, employment statistics, features of the built environment, infrastructures lay-out, pollution and meteorological data. Output results are scenarios of energy use and environmental conditions for the selected region. Industrial, residential, commercial and infrastructures sites location and lay-out can be also determined based on the output results. This model can be employed for the evaluation of policies and actions for efficient communities' implementation.
The possibility of having benchmarks and good practices for community scale environmental responsible interventions is today a critical issue. In this field a recently developed environmental quality certification protocol is LEED (Leadership in Energy and Environmental Design) for Neighborhood Development. This rating system, that extends some of the benefits of good building practices into the community level, is developed by US Green Building Council and derives from the LEED protocol for buildings. The scope beyond this protocol is to integrate smart growth and green building design principles in neighborhood design. Although this environmental quality certification system is not strictly focused on energy planning as previously described PLACE3S methodology, it highlights the need for multicriteria decision making methods for the design of solutions at the community level and, consequently, must be considered as an interesting example of systemic design approach.

3.4 Tools under development

In this paragraph some tools currently under development are described. In the field of simulation tools a model which is under development at IEE (Institute for Energy Engineering) of the Technical University of Berlin is XEONA (eXtensible Entity-oriented Optimization-based Network-mediated Analysis) (Bruckner et al. 2005). It is an object-oriented simulation environment that models the technical and commercial complexity of energy systems facing the multicriteria nature of energy policy problems, in a context of market liberalization. This model can be used for measuring energy policy impact like, for example, the possible paradigm shift towards DG in a deregulated competitive market. Another simulation model is H2RES (Krajacic et al. 2009) developed within the UE Commission founded projects RenewIslands and ADEG. This model is designed for balancing hourly electricity, heat and hydrogen demand with supply from wind, solar, hydro, geothermal, biomass, fossil fuels, national grid and storage systems. The main purpose of this model is energy planning and techno-economic feasibility evaluation of stand-alone systems DG system project under constraints. To conclude, ODESSE is a simulation and optimization tool for green building and district energy simulation currently under development at ENEA (Italian Agency for New Technologies, Energy and Environment). This model has:

- a component for a dynamic energy demand simulation for a monozone building;
- a component for a dynamic energy demand simulation for a multizone building;
- a set of components for integrating electricity, heating and cooling production and optimization.

The possibility of extending the capabilities of tool to district is under development.

3.5 A new methodological approach for a new model

Our approach in providing the development of a “home made” simulating model takes into account firstly the importance to act on three sides of energy system (reducing energy demand; optimizing generation systems and implementing advanced management control systems).
The model and relative computational framework are developed in order to transform energy systems at district level optimizing energy, environment and economic aspects at the same time and within a specific site. In this operation, many capabilities of the previously described tools are involved, for example, GIS are essential for storing, organizing, visualizing spatial data and performing spatial calculation. After that, accounting, simulation and optimization techniques have to be employed to correctly design distributed generation systems. Finally impact assessment must be addressed by calculating local pollutant dispersion, external costs and performing LCA.
The proposed computational framework could be considered as a simplified version of an automated energy management system whose aim is finding the most efficient way to provide electric power and heating (and cooling where requested) to customers by exploiting on-site renewable energy sources and conventional sources, able to extend the capabilities of forecasting and optimization tools to the particular implementation within a district.
A synthetic explanation of the different parts of the suggested model is given in the following paragraphs.

3.5.1 Preliminary phase

Data related to the district have to be collected and stored in datasets and GIS to enable fast and accurate spatial calculation in the preliminary phase. In an energy management system, a large amount of disaggregated data are needed and processing techniques are fundamental to extract useful information. Energy flows monitoring system for both demand-side and supply-side is necessary and different layers of information have to be organized to allow interoperable data interchange between computational tools. The data employed in the preliminary phase are: building data (general dimension, heated ground area, etc.); activity types (residential, commercial, offices, industrial, etc.); energy consumption data (natural gas and electricity consumption from utility); electric load profiles data (statistics from utility); energy tariffs and fuel costs; climatic data (one hour resolution).

3.5.2 Pre-processing phase

The pre-processing phase starts from historical data series analysis. Forecasting techniques are employed to simulate hourly electric loads and thermal loads. Loads are calculated for a typical meteorological year and are inputs for the sizing and dispatch optimization procedure.
In the design work phase loads can be also simulated with general models (for example in case of newly built districts), but the use of real metered data is necessary in existing district.

3.5.3 Design phase

The analysis is performed in two steps: plant sizing and economic dispatch optimization. The complete computational procedure is multiobjective, because economic and environmental performances for many different plant sizing configurations are considered.

3.5.4 Post-processing phase

In the optimization procedure uncertainty has to be correctly taken into account via sensitivity analysis or more sophisticated numerical techniques, like stochastic optimization, because conventional techniques may provide solutions that perform well in the design point, but whose performance decrease rapidly as we move away from it. It is necessary to verify the robustness of the solutions due to uncertainty and variability in input parameters. In any case the scope of post-processing phase is organizing and analyzing output results from the design phase.

3.5.5 Impact assessment phase

The impact assessment is the final work phase. This phase uses outputs from the previous phases in order to determine local and global pollutant emissions effects, calculate external costs, perform LCA analysis and provide the basis for a correct local distributed generation.

4. CONCLUSIONS

The transition towards more efficient district energy paradigma implies first the reconsideration of where customers from residential, commercial, industrial and transportation sectors are located and how they can reduce their demands while satisfying their needs. A correct demand side management is the first step, because it offers the largest potential for energy saving in many different areas. Beside that, the production of energy vectors in a local efficient polygeneration system can result in an improved use of available energy resources, lower costs and reduced emissions and environmental impact. Additionally both demand and supply side must be monitored in real world application in a continuous way to provide useful information. In this sense, the supporting computational framework should own the main features of an advanced local energy management system and must provide not only the correct sizing and economic dispatch optimization, but also useful insights on monitoring and control strategies.

On the other hand, local energy policy has to deal both with local and global impact. Local and global dimension are today more strictly connected also because of the international power exchanges permitted by liberalization and depending on the electricity market condition. So, the correct exploration of possible alternatives in energy systems is essential to enable a scientific, transparent and responsible decision making process. This process is intrinsically multidisciplinary and multiobjective: many disciplines and expertise are integrated in a common workflow and the task is either to maximize or minimize several conflicting objectives like, for example, costs, global pollutant emissions and local pollutant emissions. Beside that, the introduction of energy efficient technologies and practices has to be properly evaluated in terms of costs and benefits, life cycle energy and environmental impact.

All these issues comprise a very high level of complexity and it is very hard to predict the real effects of defined measures and actions. To that end innovative and interoperable models for energy systems design and for technical and economic feasibility evaluation need to be improved.

The computational framework under development constitutes a simplified version of what should be a district scale energy management system and represents a first effort towards the definition of system design principles. The developed tool is now available in a draft version that is being tested in referring to actual cases of study, but first results confirm the capability of the model in relation to the defined aims and targets.

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