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AN OVERVIEW OF EUROPEAN RESEARCH PROJECTS FOR SMART CONTROL OF ENERGY SYSTEMS

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ABSTRACT

The European Union is funding scientific research through the Horizon 2020 program. Since the key priorities for the next few years are to reduce carbon emissions and enhance the efficiency of energy systems, a collection of the most recent research projects can be beneficial for researchers who want to easily access and identify recent innovation in the energy sector. This paper proposes an overview of the studies on distributed energy systems and their efficient management and control with the purpose of reducing energy consumption. The characteristics of the projects are summarized and the relevant expected outputs are described. Moreover, the main features that should be tackled to obtain smart, optimized and digitalized energy systems are presented.

Keywords: European research projects, digitalization, smart district heating and cooling network, energy efficiency in buildings, intelligent management and control, optimization

NOMENCLATURE

Abbreviations	
DHC	District Heating and Cooling
EU	European Union
MPC	Model Predictive Control

1. INTRODUCTION

The Energy Challenge is universally recognized as one of the key priorities to be addressed in the present and future, in order to mitigate climate change and reduce humans' impact on the environment. Since 2007, fundamental targets have been set by the European Commission. The *Clean Energy for All Europeans package* sets two new targets for the European Union (EU) for 2030: a renewable energy target of at least 32 % and an energy efficiency target of at least 32.5 % [1].

In order to reach these objectives, the EU is currently supporting research – from 2014 to 2020 – through the *Framework Programme for Research and Technological Development FP8*, known as Horizon 2020 [2]. Horizon 2020 aims to contribute to the realization of a knowledge- and innovation-driven society and aims to achieve the key priorities for 2020: intelligent, sustainable and inclusive growth. In this framework, "*Secure, Clean and Efficient Energy*" is recognized as one of the major "*Societal Challenges*" of the near future. In particular, according to one of the calls for proposals [3], growing attention is given to District Heating and Cooling systems (DHC) which have to be "*more efficient, intelligent and cheaper*". Therefore, "*it is necessary to develop and deploy intelligent systems using smart metering and control solutions for optimization*" and to exploit multiple energy resources, including renewables.

It would be helpful for researchers and practitioners to have available a detailed overview of the research and innovation projects, in order to keep track of recent interests, funding opportunities and developments. However, this is still lacking in the literature, since the numerous reviews are limited to scientific papers. In this work, the most recent Horizon 2020 research projects in the sector of energy distribution management and control are reviewed and catalogued according to their objectives, main output and relevant features.

2. METHODS

The construction of a specific map of the Horizon 2020 projects may be a non-trivial task as the projects

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are often broad and individual work packages are distributed to different research groups. Moreover, preliminary results and public information may be difficult to find. In late 2017, Moseley [4] highlighted and addressed this issue presenting a detailed and comprehensive review of recent and ongoing Horizon 2020 research, innovation and market uptake projects on "smart buildings" for energy efficiency enhancement at building level. Here, a similar approach is adopted to gather the works that focus on the development of smart tools and approaches for DHC control, comprising district level, building level and their integration.

A close examination of the Community Research and Development Information Service [5] has been carried out. This portal aims to provide information on all EU-funded research projects, containing a general description and, in some cases, results in brief. Keywords for the research were "District Energy", "District Heating and Cooling", "Optimization", "Intelligent Control and Management". Special attention has been paid to work activities that involve Model Predictive Control (MPC) techniques, as this is a well-known and verified control strategy in the field of chemical and industrial processes but its further application to district energy is still needed. Additional information on each project has been gathered from the dedicated website and dissemination material. Moreover, science databases have been searched for potential publications from the main research groups involved in the projects, in order to track the preliminary results of ongoing projects and possible outcomes.

For each project considered relevant for the scope, the main features have been highlighted in order to define a complete research and innovation framework and to observe potential scientific and technological gaps that can be tackled in future activities. These features, which are outlined in Table 1, regard the energy carrier, major application, expected output and methodologies.

Table 1. Features for the identification of projects that involve intelligent distributed energy systems.

Feature		Explanation
Energy vector		The energy carriers involved can be thermal power, cooling power, electricity or natural gas.
Application	Grid/District	The project work is applied at grid or district level, generally involving a multi-source complex energy system.
	Building	The project work is applied at building level.
Main output	Software/ Platform	The scope of the activity is to create a software, a platform, a web application or a framework for research and industries.
	Model/Library	The scope of the activity is to create a model or a library of models for the effective simulation of buildings or energy system components.
	Optimization tool	The activity consists of the application of an optimization algorithm for the minimization or maximization of an objective.
	Business model	The activity aims to create a new business model for industrialization or dissemination.
Purpose	Planning	Long-term (annual) planning and scheduling of the system is performed.
	Sizing/Design	The sizing and design of the distribution grid, generation systems and loads, additionally considering the topology, are carried out.
	Retrofitting	The addition of innovative technology to existing systems is evaluated.
	Real-time control	The innovative intelligent real-time control strategies are implemented and tested.
	Monitor/ Management	System monitoring is performed through smart meters, sensors and overall system management to achieve a certain goal.
	Diagnosis	The methodology is developed to perform system diagnosis or fault detection.
	MPC	The Model Predictive Control (MPC) technique is applied: control action is optimized based on the future evolution of the system predicted through a mathematical model.
	Self-learning/AI	Autonomous learning and Artificial Intelligence (AI) techniques are used for classification and identification of models through Big Data.
Other	Forecasting	Forecasting of weather conditions, energy demand or external disturbances are implemented.
	LCA/LCC	Life Cycle Analysis or Life Cycle Cost are performed to evaluate the global environmental or economic impact of the system.
	Demand Response	Demand Response strategies are integrated in order to adjust energy demand to match the supply through engaging customers in the process.
	Peak shaving	Strategies for the elimination or leveling of peak loads are evaluated.
	Storage	Energy storage is accounted as a key component to provide flexibility.
	Integration	Renewable energy sources are integrated.

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3. RESULTS AND DISCUSSION

The analysis resulted in 37 Horizon 2020 work activities the characteristics of which are summarized in Table 2. The additional materials and documentation are gathered in a database which can be periodically updated with the current results.

Overall, more than half of the projects aim to build a software or web platform that can efficiently help researchers and stakeholders monitor and manage complex energy systems and show the trend toward the digitalization of the sector. Likewise, these projects propose the implementation of optimization algorithms to minimize the energy consumption or cost. In thirteen projects, one of the main outputs is a smart real-time control strategy, which shows the importance of system control in enhancing its efficiency. For instance, E2District [13] developed a District Simulation Platform with an adaptive controller while STORM [37] developed a smart controller based on self-learning optimization techniques, such as neural networks. The FLEXYNETS project [15] built a small scale experimental test rig to emulate a thermal network and test different operation strategies. The HEAT4COOL project [17] proposed a Self-Correcting Intelligent Building Energy Management System that has real-time feedback and regulation functionalities for the optimization of energy usage. Despite their effectiveness, classical, rule-based and adaptive methods do not consider the prediction of future conditions. Predictive controllers, which might be able to overcome this limit, have been proposed by the TOPAs project [42], which applies MPC to single building environments. At district level, INDIGO [21] and OPTi [29] implemented MPC within integrated toolsets for a cooling system and a district heating network, respectively.

To conclude, the most relevant tools that should be addressed to reduce the environmental impact of the energy distribution sector are optimal control (e.g. MPC), digitalization and system automation.

4. CONCLUSIONS

An overview of the most recent Horizon 2020 research projects with the aim of making distributed energy systems smarter is presented in this paper by outlining the latest developments, goals and outputs on this topic. Special attention is paid to the projects that are relevant for the optimization and management of district heating and cooling networks. Moreover, it sets the basis for funding opportunities within the next research and innovation program Horizon Europe.

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Table 2. Relevant features of Horizon 2020 projects.

Project	Energy vector				Appl.		Main Output				Purpose								Other features					
	Heating	Cooling	Electricity	Gas	Grid/District	Building	Software/Platform	Model/Library	Optimization tool	Business model	Planning	Sizing/Design	Retrofitting	Real-time control	Monitor/Management	Diagnosis	MPC	Self-learning/AI	Forecasting	LCA/LCC	Demand Response	Peak shaving	Storage	integration
4RinEU [6]	✓	✓				✓	✓			✓			✓											✓
CHESS-SETUP [7]	✓	✓	✓		✓	✓	✓		✓	✓		✓			✓								✓	✓
Cool DH [8]	✓	✓			✓	✓				✓		✓	✓											✓
CoolHeating [9]	✓	✓			✓					✓														✓
Create [10]	✓					✓							✓										✓	✓
DR-BOB [11]			✓			✓	✓		✓						✓						✓		✓	
DRIvE [12]			✓		✓		✓								✓				✓		✓			✓
E2District [13]	✓	✓			✓	✓	✓	✓	✓	✓				✓	✓	✓		✓		✓			✓	✓
EnergyMatching [14]	✓		✓		✓	✓			✓	✓					✓			✓						✓
FLEXYNETS [15]	✓	✓			✓			✓		✓				✓	✓								✓	✓
H-DisNet [16]	✓	✓			✓			✓		✓				✓				✓					✓	✓
Heat4Cool [17]	✓	✓	✓		✓	✓			✓	✓		✓	✓	✓	✓			✓			✓			✓
HIT2GAP [18]	✓	✓	✓			✓	✓	✓							✓	✓		✓	✓					
HOLISDER [19]	✓		✓	✓	✓	✓			✓	✓					✓			✓			✓		✓	
InDeal [20]	✓	✓			✓	✓	✓								✓			✓	✓				✓	✓
INDIGO [21]		✓			✓		✓	✓	✓		✓	✓		✓	✓		✓	✓	✓					✓
InteGRIDy [22]			✓		✓		✓		✓	✓									✓		✓		✓	✓
LOWUP [23]	✓	✓				✓																		✓
MAGNITUDE [24]	✓	✓	✓	✓	✓		✓		✓	✓														
MOEEBIUS [25]	✓		✓		✓	✓		✓	✓	✓			✓	✓		✓			✓	✓		✓		✓
MPC-: GT [26]	✓					✓		✓	✓			✓		✓			✓							✓
NewTREND [27]					✓	✓	✓	✓		✓		✓	✓							✓				✓
OptEEmAL [28]	✓	✓			✓		✓		✓			✓	✓					✓		✓				
OPTi [29]	✓	✓			✓		✓	✓	✓					✓			✓	✓	✓		✓	✓		
PENTAGON [30]	✓	✓	✓	✓	✓	✓	✓								✓			✓					✓	✓
Plan4Res [31]	✓	✓	✓	✓	✓		✓	✓			✓				✓									✓
PLANET [32]	✓	✓	✓	✓	✓		✓	✓	✓		✓				✓								✓	
Planheat [33]	✓	✓			✓		✓				✓								✓					✓
RELaTED [34]	✓				✓																			✓
RESPOND [35]	✓		✓		✓	✓			✓					✓	✓						✓			
Spine [36]					✓			✓																
STORM [37]	✓	✓			✓	✓		✓	✓					✓	✓			✓	✓			✓	✓	✓
STORY [38]	✓		✓		✓			✓		✓				✓	✓				✓				✓	
TEMPO [39]	✓				✓	✓	✓		✓	✓		✓	✓		✓									✓
THERMOS [40]	✓				✓		✓	✓	✓		✓				✓									
THERMOSS [41]	✓	✓			✓	✓	✓						✓		✓									
TOPAs [42]	✓					✓	✓	✓	✓					✓	✓	✓	✓	✓						

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