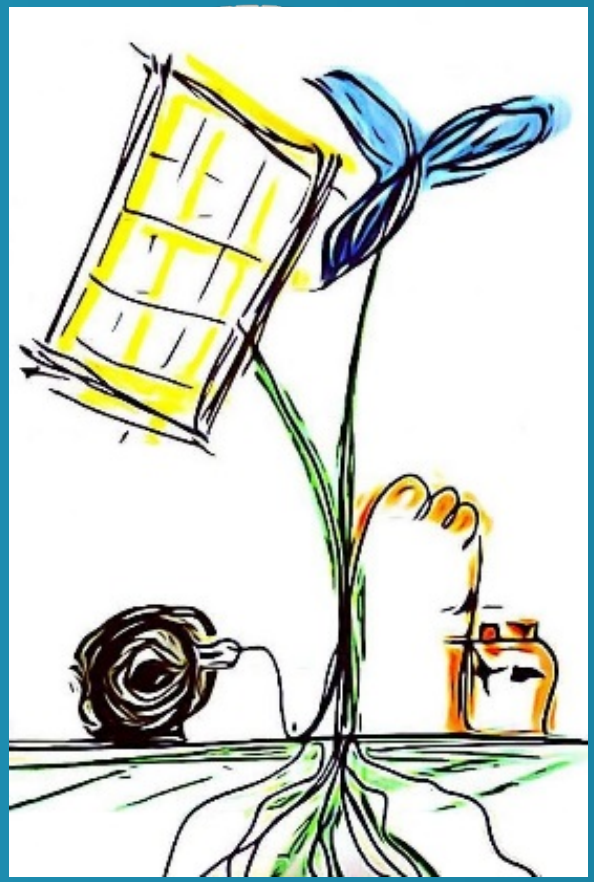


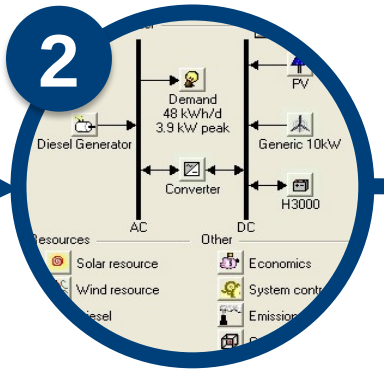
ElectrifyMe.org:
Research studies, trends and opportunities for researcher's community integrating renewables off-grid

Mar Martínez-Díaz

30 November 2017, Newcastle
Symposium on Microgrids, Australia

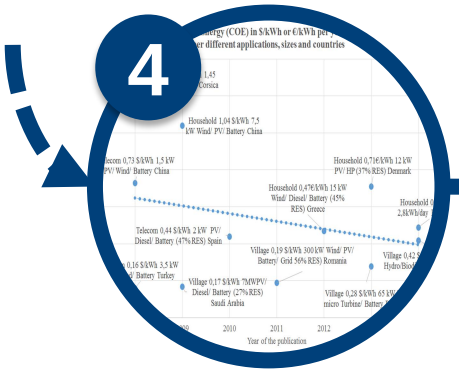
Energy Poverty
The Problem

Renewables Off-grid
The Challenge

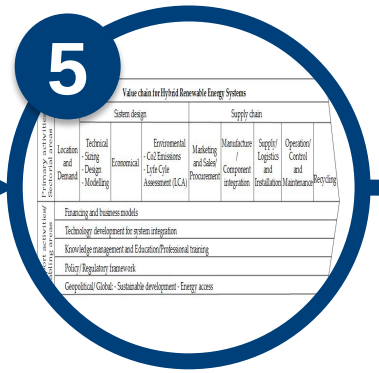


Design criteria
The Study case

Scanning Innovations
The Research community



Design of HRES
Beyond economic criteria

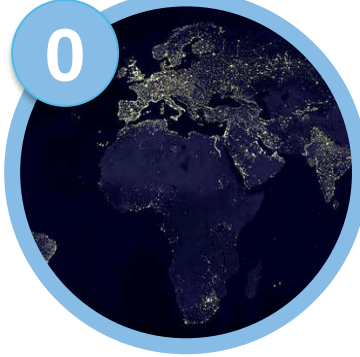


+ Integration
Value Chain

+ Multidisciplinarity
www.Electrifyme.org
(Knowledge transfer & valorization)

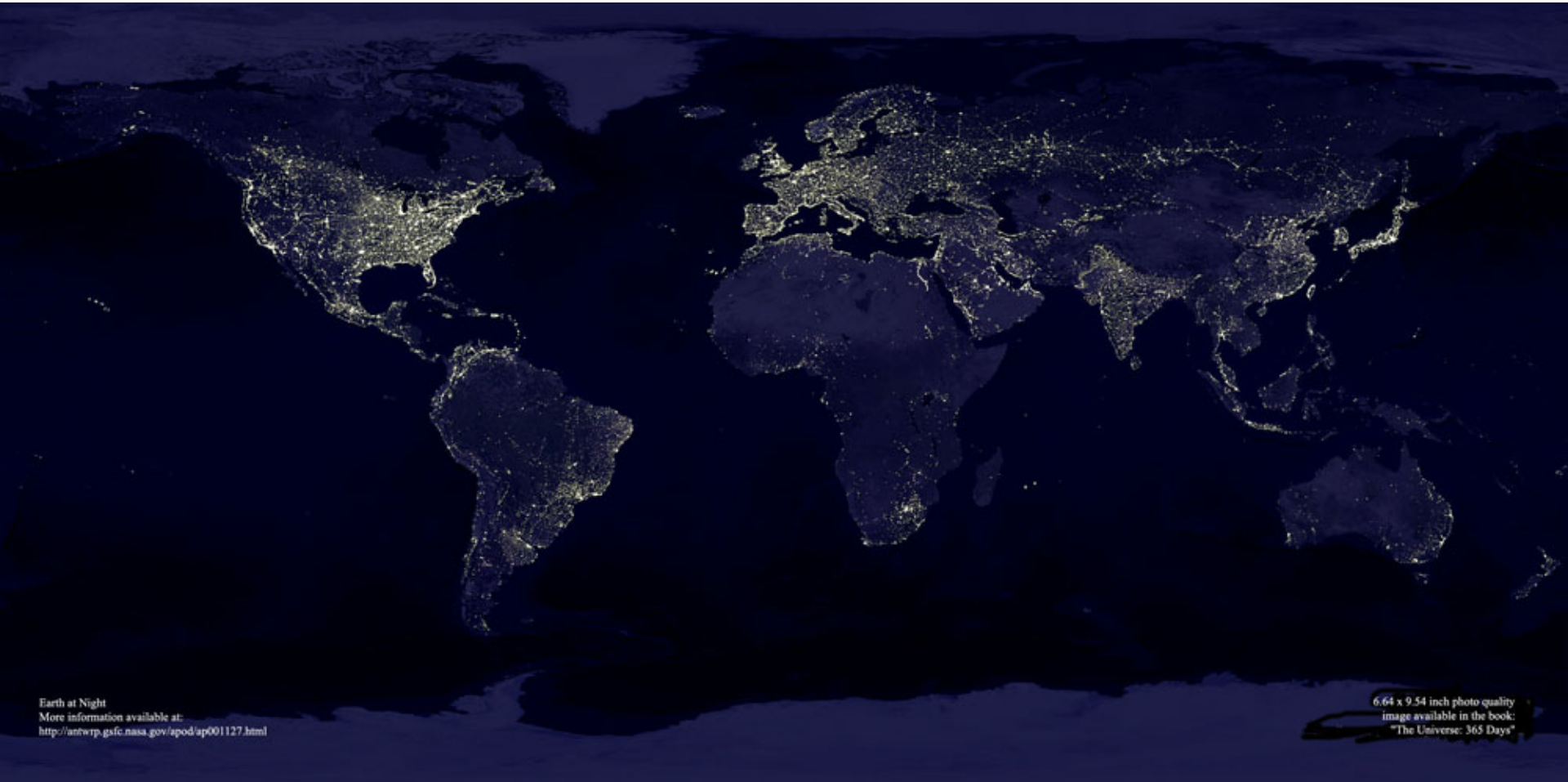
Main contributions
So, what next?
(Conclusions & Future work)

Energy Poverty- The Problem
(Introduction & Context)



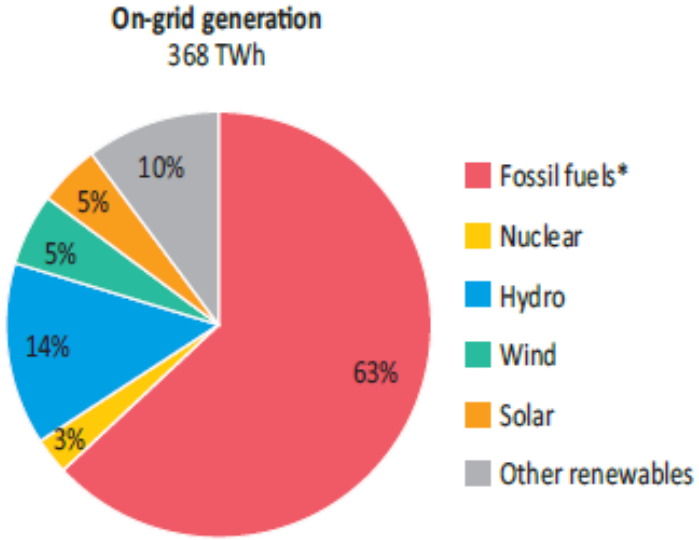
- 1 out of 7 people lack access to electricity:

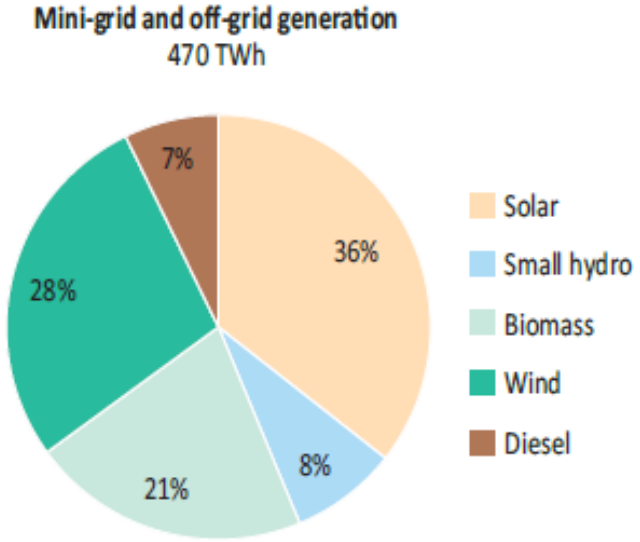
1,3 billion people in the world



The Sustainable Energy for All (SE4ALL) initiative by United Nations

- The goal of the SE4ALL scenario is to "ensure universal access to modern energy“ by 2030 and to "double the share of renewable energy in the global energy mix".

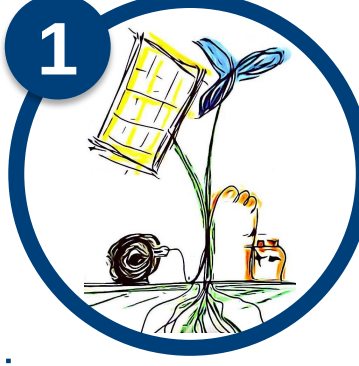




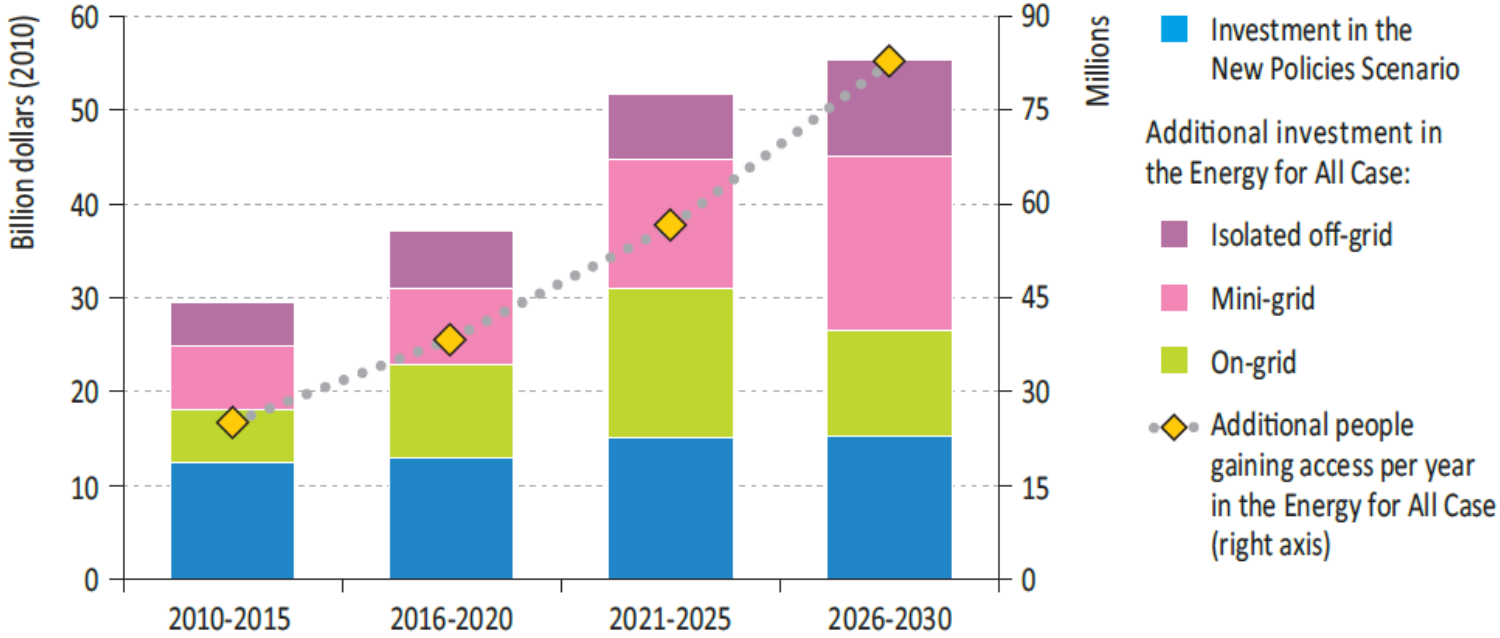
- Of the additional electricity needed in 2030, an increase in global electricity generation of 2.5% (around 840 TWh), around 45% is expected to be generated and delivered through extensions to national grids, 36% by mini-grid solutions and the remaining 20% by isolated off-grid solutions [5].

[5] http://www.worldenergyoutlook.org/media/weowebsite/energydevelopment/weo2011_energy_for_all.pdf

Renewables Off-grid- The Challenge



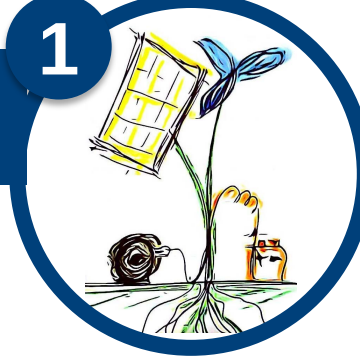
- The potential of introducing renewable energy resources off-grid via renewable hybrid energy systems (HRES) is impressive:



- The International Energy Agency (IEA) estimated in 2011 nearly $1 trillion of investment is required to achieve universal access to energy by 2030. 60% of these investments, $20 billion annually, are expected to be in isolated off-grid and mini-grid solutions.

[5] http://www.worldenergyoutlook.org/media/weowebsite/energydevelopment/weo2011_energy_for_all.pdf

What are Hybrid Renewable Energy Systems (HRES)?



- Hybrid Renewable Energy Systems (HRES) can be found under different terms and definitions:

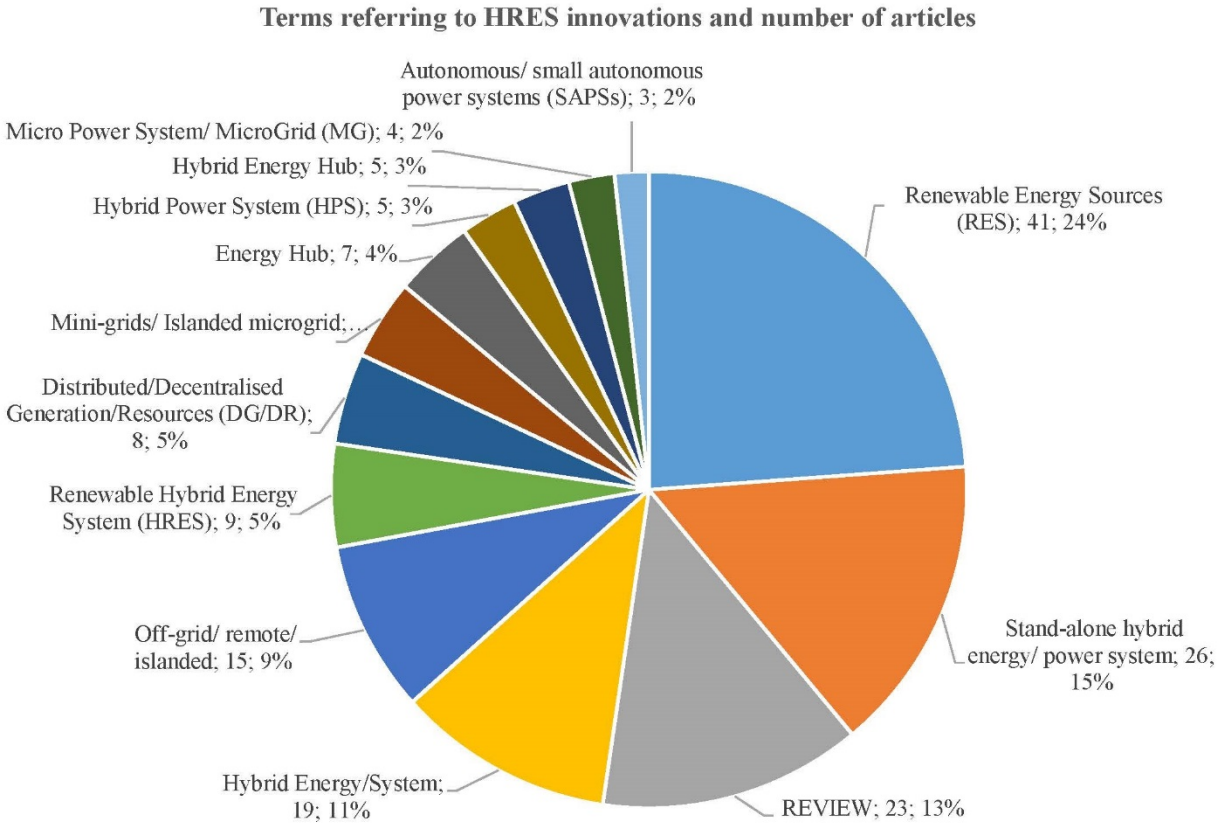


Figure 1.2: More than 12 terms for HRES (total 172 publications, period 2005-2015)

The data and information being scattered and in silos is a barrier for knowledge sharing

Renewables Off-grid
The Challenge

1

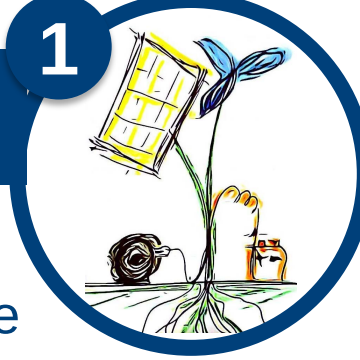
- Climatetagger, with the support by IRENA and the United Nations Environment Programme (UNEP), is a joint tool developed to improve efficiency and performance of knowledge management systems for climate change.

http://www.climatetagger.net/renewables-thesaurus/tree

I propose the following general definition for HRES:

"Hybrid Renewable Energy Systems (HRES) consist of
two or more energy sources,
with at least one of them renewable
and integrated with power control equipment,
and an optional storage system."

What are the key design & decision criteria for HRES?



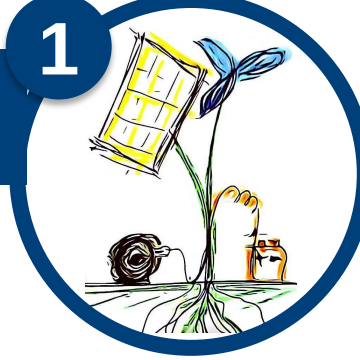
- Key factors for the design & decision-making of a stand-alone renewable hybrid power system are multiple factors depending on, e.g.:
  - Economic aspects: Net Present Cost (NPC), Cost Of Energy (COE), etc.,
  - Technical variables: Excess of Electricity (EE), State of Charge of the Batteries (SOC), etc., and
  - Environmental factors: Renewable Fraction, CO2 emissions, etc.

	Design criteria	Decision criteria
Economic	$	$ $ $ $
Technical	🔧 🔧 🔧 🔧	🔧
Environmental	☘	☘

The research question of this work is twofold:

Renewables Off-grid
The Challenge

1



- Shortcomings of the state of the art:
  - HREs are found under many terms and definitions.
  - Economic criteria predominate for decision making, while technical system design predominate in research work, both lacking a more integrated approach including environmental or other criteria.
- The research focus of this work is:

  How to enhance the research of stand-alone Hybrid Renewable Power Systems:

  • beyond economical optimization of the system,

  identifying other relevant criteria and research opportunity,

  • and beyond system design,

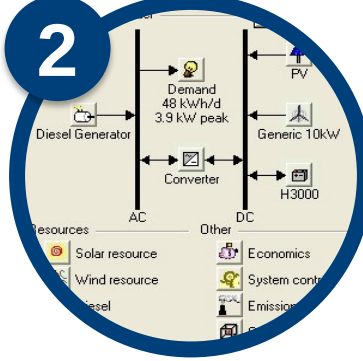
  providing a more integrated approach that create value for stakeholders,

  for a more environmentally friendly and sustainable energy access for all.

Design criteria- The Study case

(State of the art)



- Understanding design criteria sensitivity:

-> Case study (HOMER): The proposed project is a 2kW Telecommunication Center (ICT Center). It is located in the province of Tarragona (Spain).

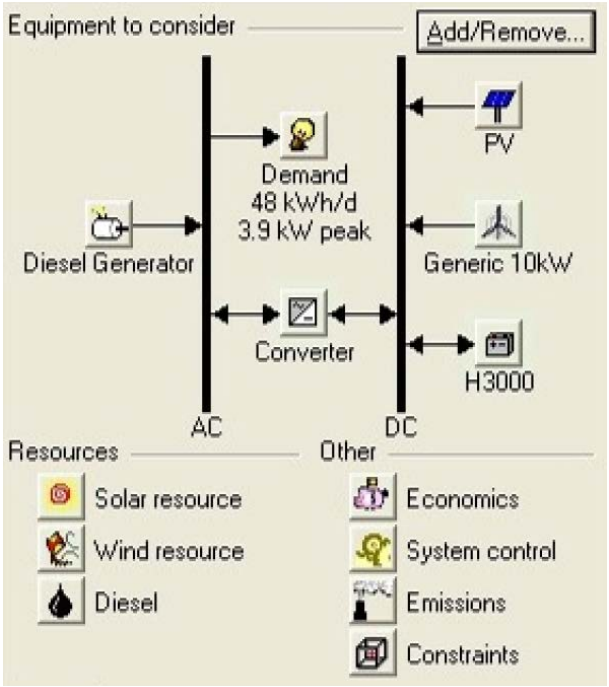
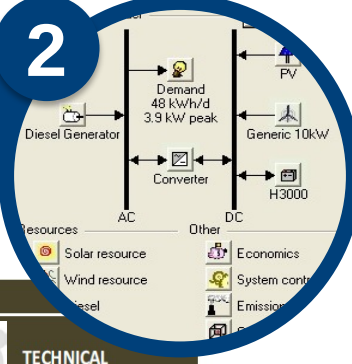


Figure A.3: Energy model for the PV/Wind/Diesel/Battery system

Image: "Tossal de Baltasana", in the province of Tarragona (Spain).

-> an increase of only 1,1% in the optimum cost the system almost double the fraction of renewable resources up to 47%!

2 Design criteria
The Study case



	POWER SYSTEMS	ENERGY MODEL: CONV. GENERATION – Diesel Generator	ENERGY MODEL: RENEWABLE GENERATION – PV	ENERGY MODEL: RENEWABLE GENERATION – Wind Turbine (10kW)	ENERGY MODEL: STORAGE – Battery (3000 Ah)	OPTIMISATION CRITERIAS: ENVIROMENTAL – Ren. Fraction	ENVIROMENTAL – CO2 Emissions	ECONOMICAL – Total NPC	ECONOMICAL – COE	TECHNICAL – Battery Throughput	TECHNICAL – Excess Electricity
		kW	kW	units	units	%	kg/yr	€	€/kWh	kWh/yr	kWh/yr
NOT RENEWABLE	DIESEL_BATTERY	2			12	0.00	14,241	93,922	0.468	1,511	0
	DIESEL_BATTERY	5	0.000	0	0	0.00	19,565	126,547	0.630	0	2
	DIESEL	5			0	0.00	19.565	126.547	0.630	0	2
HYBRID RENEWABLE	PV_DIESEL_BATTERY	2	2.160	0	12	0.25	11,292	87,45	0.436	1,945	68
	PV_DIESEL_BATTERY	2	4.320	0	12	0.47	9,46	88,463	0.441	6,345	116
	PV_WIND_DIESEL_BATTERY	2	0.135	1	12	0.27	11,596	96,616	0.481	1,961	1,277
	WIND_DIESEL_BATTERY	2	0.000	1	12	0.26	11.727	96,691	0.482	2.016	1.203
	PV_WIND_DIESEL_BATTERY	2	4.320	1	12	0.64	7,945	97,012	0.483	6,071	2,508
	PV_DIESEL_BATTERY	5	2.160	0	0	0.25	17,347	124,722	0.621	0	536

A

C

B

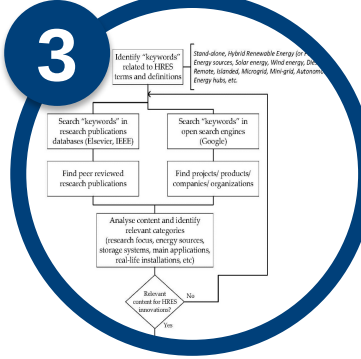
Figure 2.20: Scenarios with summary of influence for different design criteria

Key criteria:	Scenario A	Scenario B	% ΔB-A	Scenario C	% ΔC-A
NPC	0,436 €/kWh	0,483 €/kWh	10,8%	0,441 €/kWh	1,1%
Ren. Fraction	25 %	64 %	156,0%	47 %	88,0%

Figure 4.5: Key criteria per scenarios and % of variation from the optimum cost (Scenario A)

Scanning Innovations- The Research community

(Methodology & Mapping of findings)



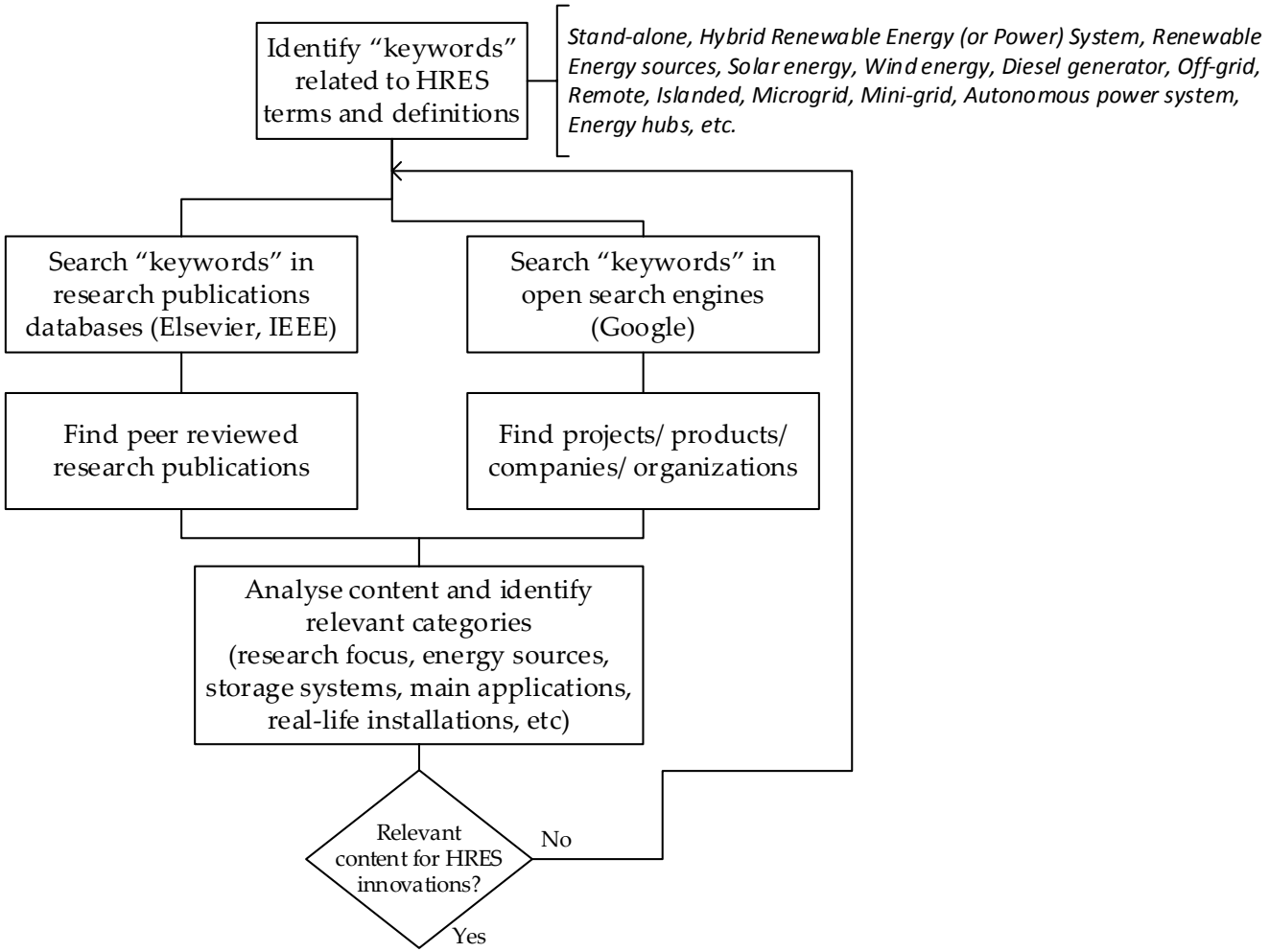
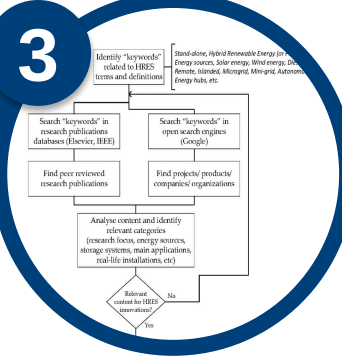


Figure 3.1: Flowchart of the building process of the primary database of HRES innovations (387 publications)

Building process of the primary database of HRES innovations - “source identification”

Scanning Innovations
The Research community
(Methodology & Mapping of findings)

3



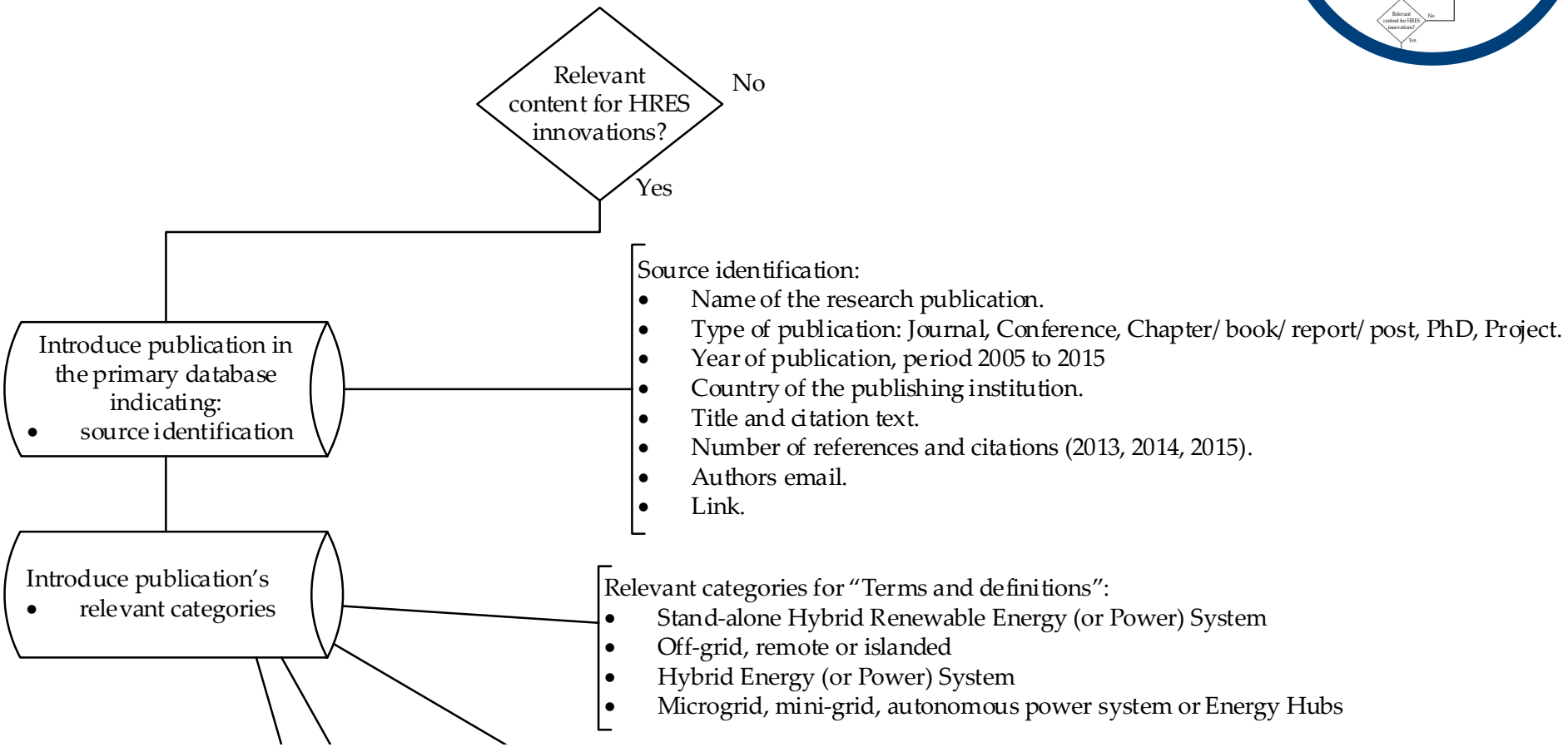
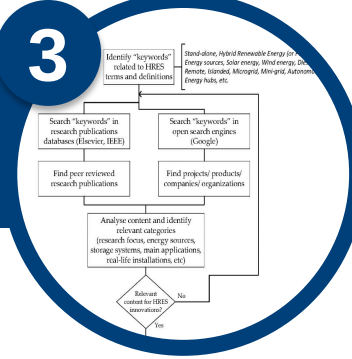


Figure 3.1: Flowchart of the building process of the primary database of HRES innovations (387 publications)

Building process of the primary database of HRES innovations - “relevant categories” (6)

Scanning Innovations
The Research community
(Methodology & Mapping of findings)



Introduce publication’s
- relevant categories

Relevant categories for “Terms and definitions”:
- Stand-alone Hybrid Renewable Energy (or Power) System
- Off-grid, remote or islanded
- Hybrid Energy (or Power) System
- Microgrid, mini-grid, autonomous power system or Energy Hubs

Relevant categories for “Thematic focus”:
- Technical focus: location , design modelling, sizing, operation/ control.
- Economical focus: value chain, economical or costs and financing, business modelling, energy markets.
- Environmental focus: CO2 emissions, tax on carbon emission, Life Cycle Assessment (LCA).
- Other aspects as broad as: education, policy, sustainable development, and energy access.

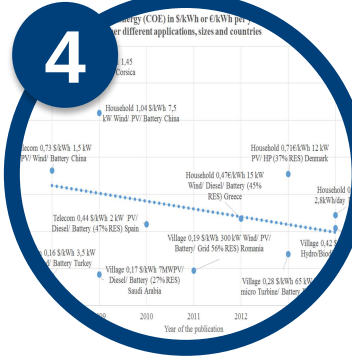
Relevant categories for “Energy sources”:
- Solar PV panels, Wind turbines, Diesel generators.
- Other renewable energy sources and clean technologies: Hydro, Biomass, Biogas, Fuel cell, CHP.
- Other non-renewable or conventional energy sources: Grid, Gas.

Relevant categories for “Storage systems”:
- Batteries, Fuel cells, Hydrogen, Pumped Hydro Storage (PHS), Thermal, or No Storage.

Relevant categories for “Main applications”:
- Households in developing countries, Global system for mobile communications (GSM) base stations, Islands, Lab tests, Villages/Communities in developing countries, Residential in developed countries, Rural areas, Street light/ Small lighting, Desalination, Case studies, Urban area, Commercial buildings/ Offices, Geographic Information System (GIS), Hospitals, Hydrogen production.

Relevant categories for “Operating installations”:
- Name of the Country, or continent.

Figure 3.1: Flowchart of the building process of the primary database of HRES innovations (387 publications)



Design of HRES- Beyond economic criteria

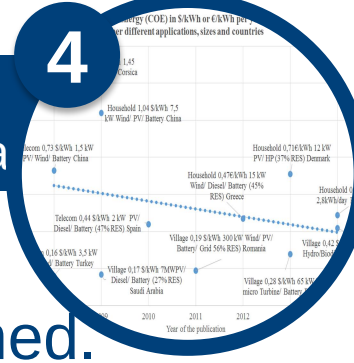
There is a current trend of developing multi-objective sizing methodologies to become reliable, feasible and/or environmentally friendly for hybrid renewable energy systems.

- Overview design criteria:
  - Economic optimization
  - Technical system Design
    - Location and Demand
    - Technical design
    - Modelling
    - Sizing
    - Operation and Control
  - Environmental criteria

Design of stand-alone HRES beyond economic optimization

Design of HRES
Beyond economic criteria

4



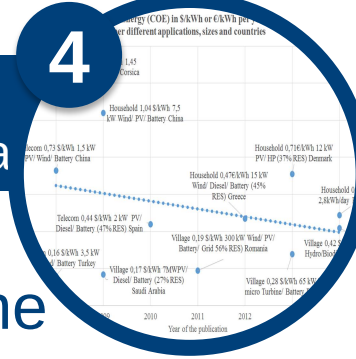
- A wide analysis of design criteria has been performed.

Location	Technical			Economic	Environment	Operation
	Sizing	Design	Modelling			
3	52	20	25	37	10	25
[14] [15] and as review: [101]	[96] [22] [21][99] [23] [52] [19][45] [49] [134] [24] [32] [87] [84] [69] [20] [8] [59] [37] [41] [38] [16] [105] [30] [34] [81] [103] [40] [44] [53] [136] [39] [14] [15] [13] [28] [9] [46] [29] [10] [12] [31] [57] [47] [42] [35] and as articles: [26] [26] [6] [92] [106] and [77]	[22] [21] [99] [52] [20] [37] [38] [103] [40] [44] [15] [13] [28] [10] [47] [64] [11] [68] [58] and as review: [72]	[96] [52] [19] [87] [84] [20] [41] [53] [39] [28] [10] [31] [47] [42] [68] [58] [104] [67] [50] [132] [33] [17] [18] [48] and [97]	[96] [7] [60] [23] [52] [19] [49] [32] [87] [84] [69] [41] [132] [25] [11] [30] [34] [103] [53] [39] [13] [9] [46] [10] [48] [47] [97] [42] [12] [58] [44] [105] [35] and as review: [6] [101] [92] and [77]	[132] [39] [13] [57] [47] [97] [52] [135] and as review: [26] and [101]	[96] [60] [107] [19] [32] [133] [67] [8] [50] [41] [43] [132] [25] [33] [44] [39] [18] [58] [9] [64] [31] and as review: [26] [6][61] and [66]

Objective Function criteria (OFC)

Design of HRES
Beyond economic criteria

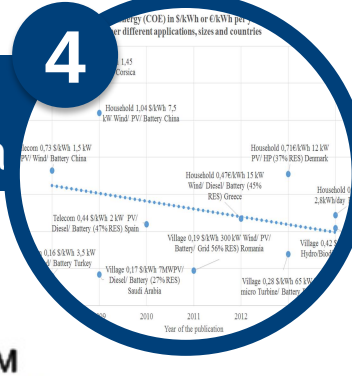
4



- The Objective Function Criteria (OFC) integrates the relevant criteria of the system design we are considering for optimization in order to:
  - serve a defined objective,
  - while taking into account the defined constrains.

- Main two criteria identified for the system optimization are:
  - the minimum Annualized Cost of System (ACS), for system cost, and
  - the required Loss of Power Supply Probability (LPSP), for system power reliability.

Objective Function criteria - conflicting objectives



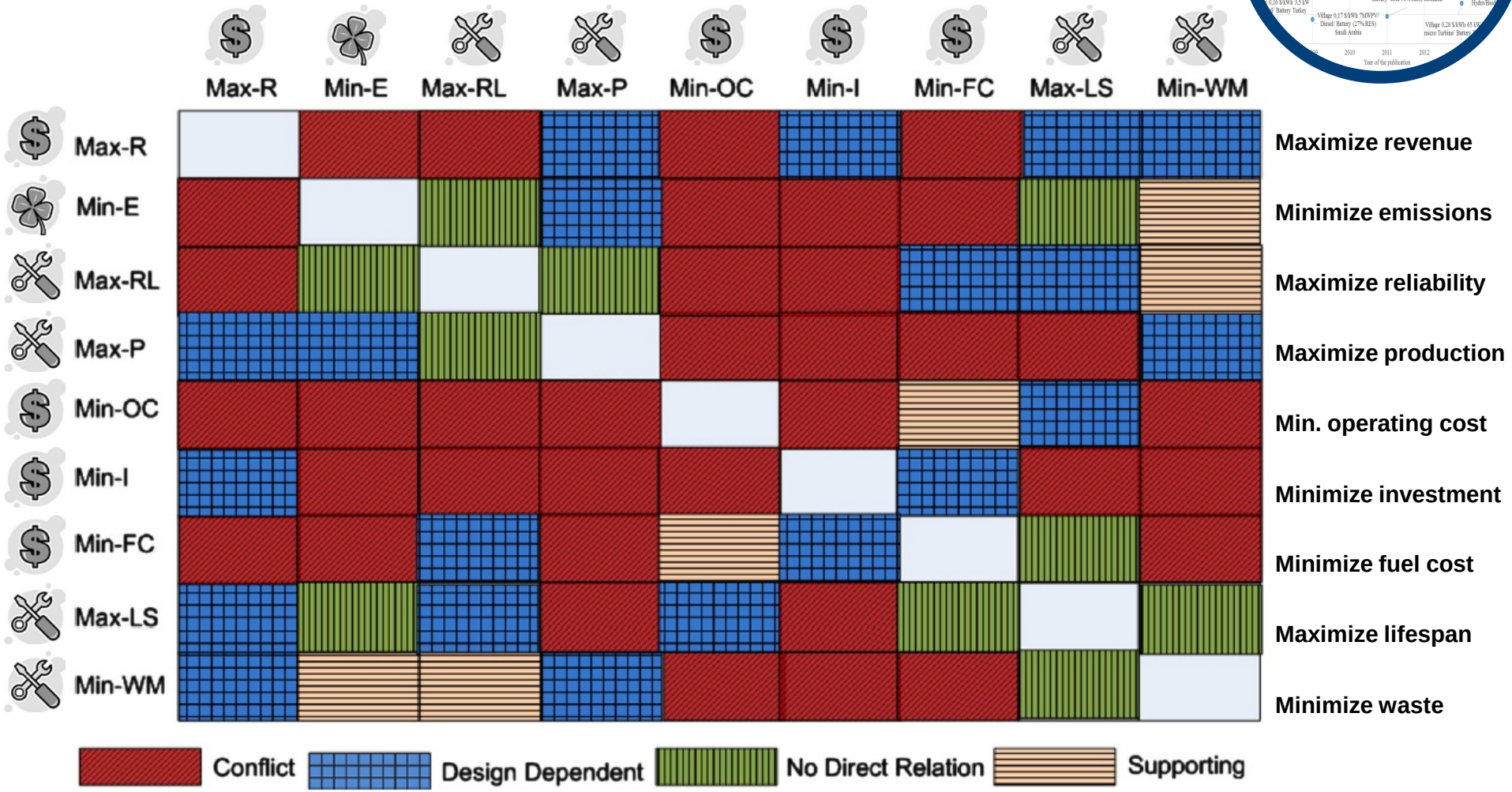


Figure 4.3: Relation between conflicting objectives [109].

Steps for a more sustainable off-grid system design (1 out of 3)

Design of HRES
Beyond economic criteria

4

1.- Use the Cost of Energy (COE) enabling comparison for different size systems, applications and countries.

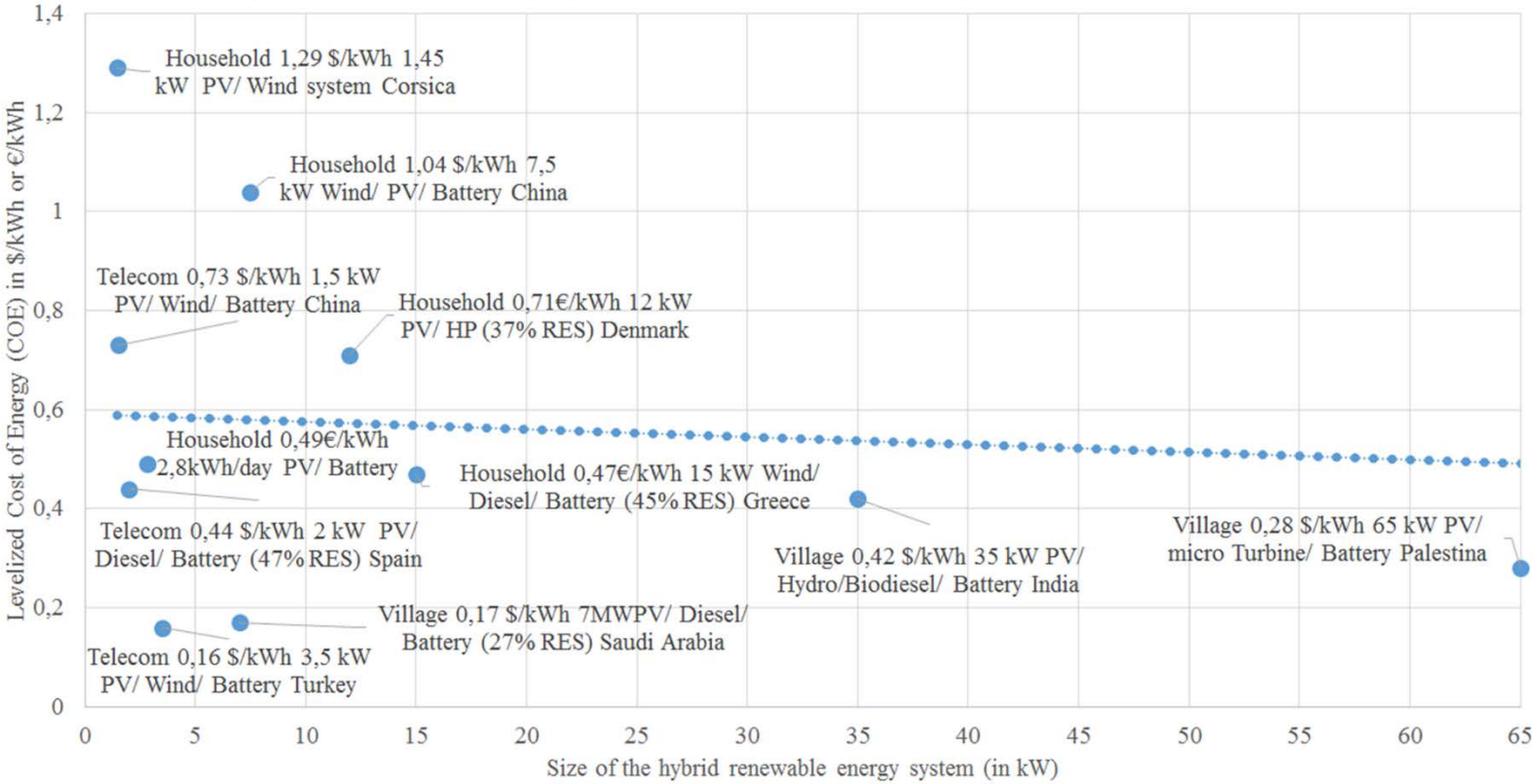
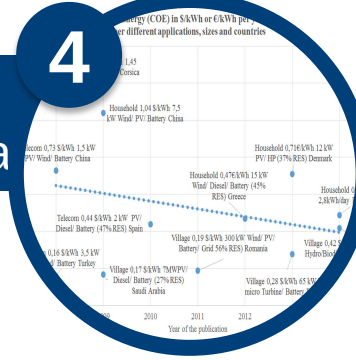


Figure 4.1: Levelized Cost of Energy (COE) in USD/kWh or €/kWh per size of the hybrid renewable energy system (in kW), per different applications and countries.

Steps for a more sustainable off-grid system design (1 out of 3)

Design of HRES
Beyond economic criteria

4



1.- Use COE enabling comparison for different size systems, applications and countries (figure 4.1).

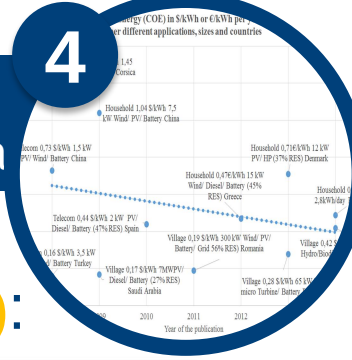
In addition, the COE enables the comparison with existing energy technology generations and systems:

- Solar cost of PV technology, minor than 0,20 USD/kWh, while
- PV reached grid parity in 2013.
- Diesel only systems, with costs higher than 1 €/kWh.
- Diesel fuel price.
- Grid availability, including the concept of radio for break-even distance.
- Grid price, different per countries.

Steps for a more sustainable off-grid system design (1 out of 3)

Design of HRES
Beyond economic criteria

4



COE enables the comparison **(with solar PV technology)**:

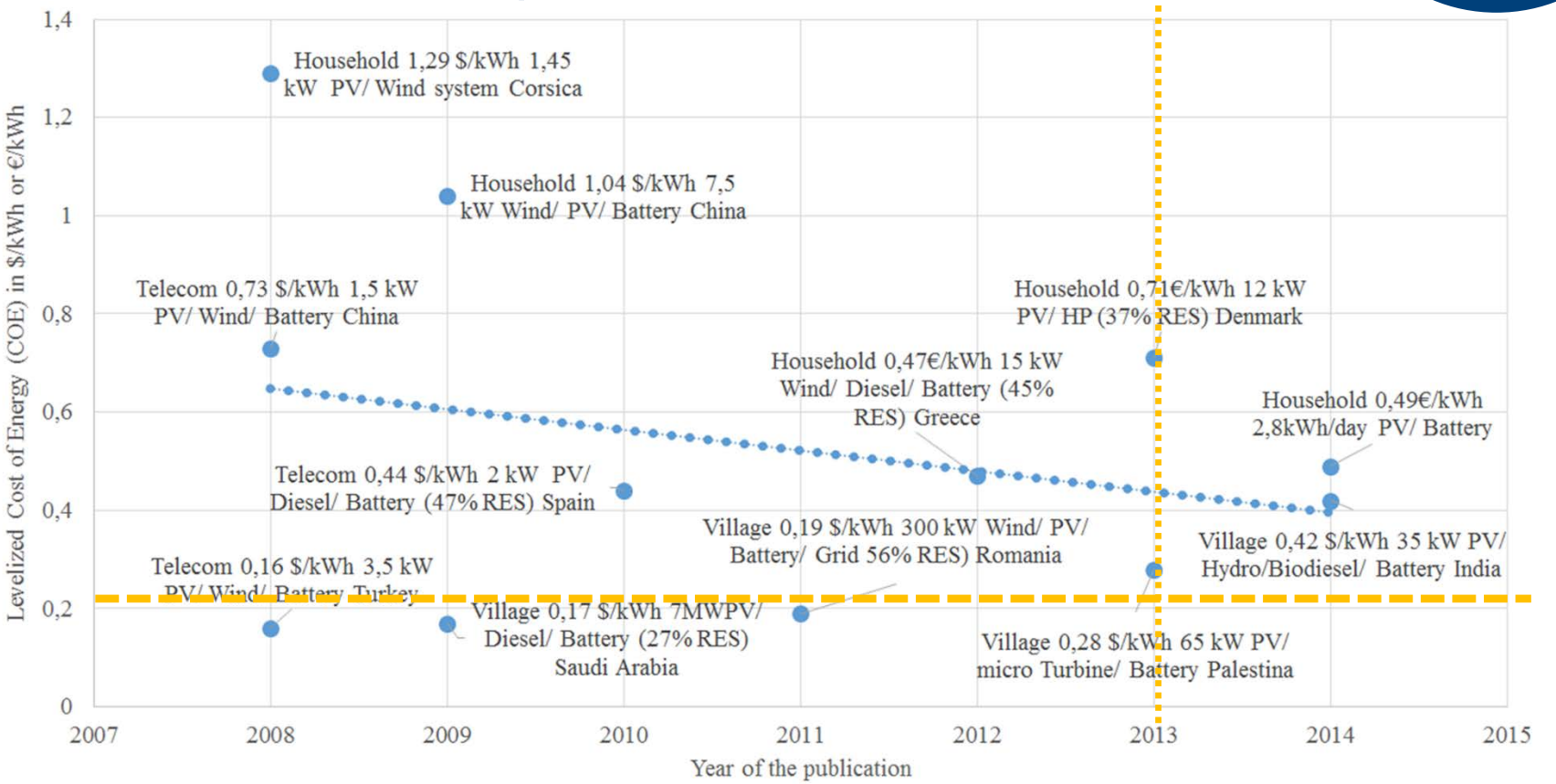
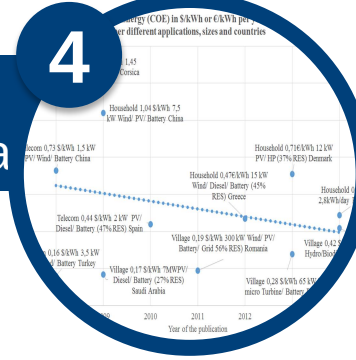


Figure 4.2: Levelized Cost of Energy (COE) in USD/kWh or €/kWh per year of publication, per different applications, sizes and countries.

Steps for a more sustainable off-grid system design (2 out of 3)

Design of HRES
Beyond economic criteria

4



2.- Focus on main cost drivers of the system components, as they are estimated to be the investment costs and the batteries such as detailed below:

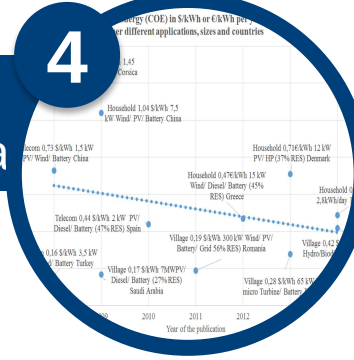
- 70% to 80% are investment costs.
- 15% to 35% are batteries costs.
- 1% to 5% are operation and maintenance costs.
- around 1% of costs are for the electrical converters.

This links to the relevance of including reliability criteria to the economic analysis and the study of back-up systems.

Steps for a more sustainable off-grid system design (3 out of 3)

Design of HRES
Beyond economic criteria

4



3.- Translate the environmental benefits to economic values, looking for a higher presence of renewable energy.

In the analyzed case study, an increase of only 1% in the optimum cost the system almost double the fraction of renewable resources up to 47%

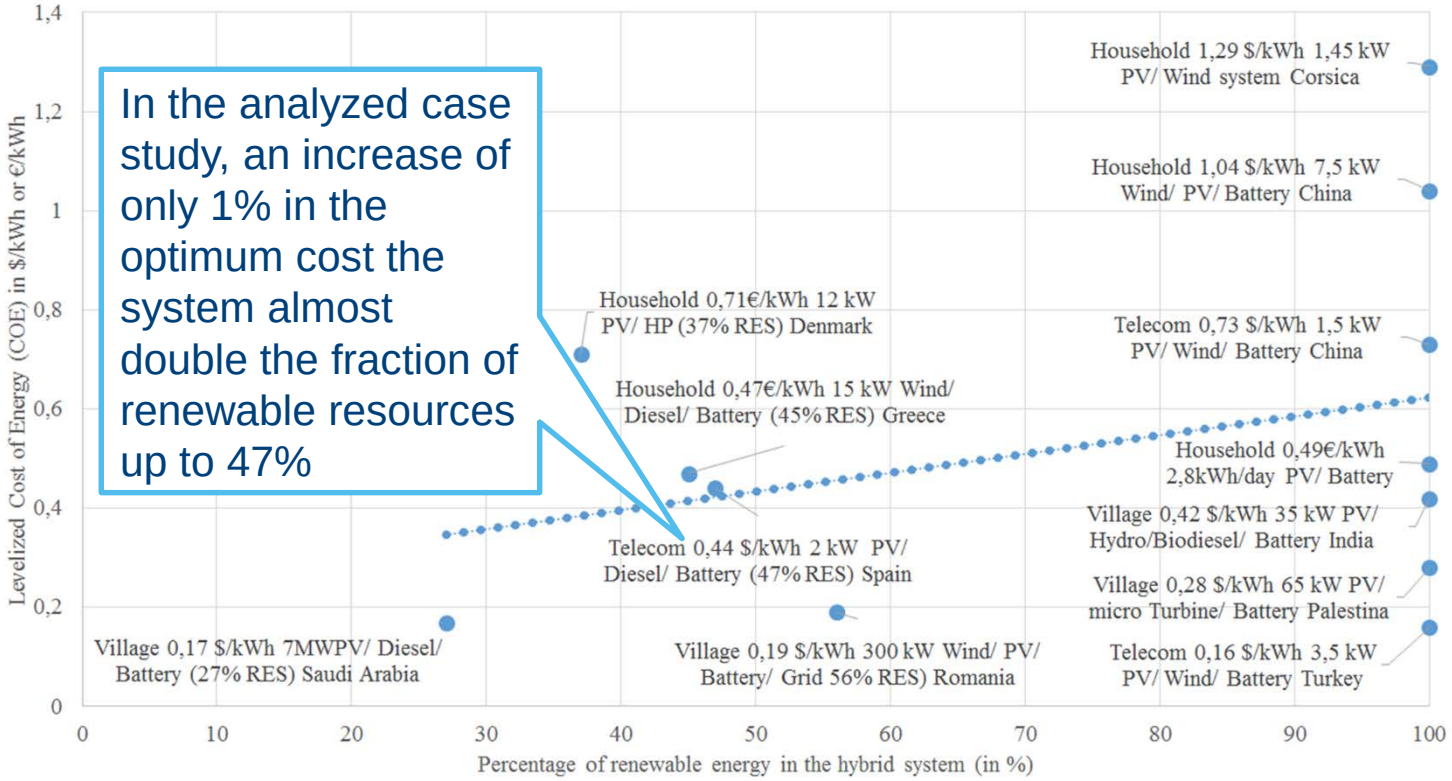
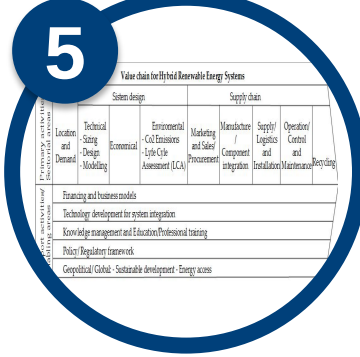


Figure 4.4: Levelized Cost of Energy (COE) in USD/kWh or €/kWh per fraction of renewable energy in the hybrid system (in %), per different applications and countries.

+ Integration- Value Chain



- Integrated Value Chain for Hybrid Renewable Energy Systems (HRES):

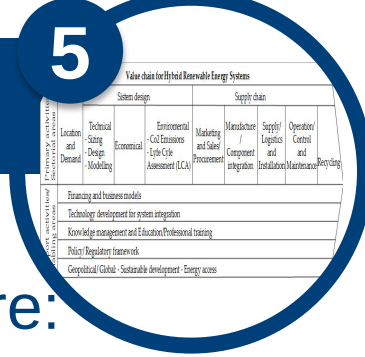
Value chain for Hybrid Renewable Energy Systems

Primary activities/ Sectorial areas	Location and Demand	Sistem design			Supply chain					
		Technical - Sizing - Design - Modelling	Economical	Enviromental - Co2 Emissions - Lyfe Cyle Assessment (LCA)	Marketing and Sales/ Procurement	Manufacture / Component integration	Supply/ Logistics and Installation	Operation/ Control and Maintenance	Recycling	
Support activities/ Enabling areas	Financing and business models									
	Technology development for system integration									
	Knowledge management and Education/Professional training									
	Policy/ Regulatory framework									
	Geopolitical/ Global: - Sustainable development - Energy access									

-> The proposed integrated Value Chain for HRES takes into account the different stakeholders and how their primary and support activities are creating and adding value for them and for the costumers or end users, in a broad sense of market, society and environment welfare.

More integrated approach beyond system design & economic criteria

+ Integration
Value Chain



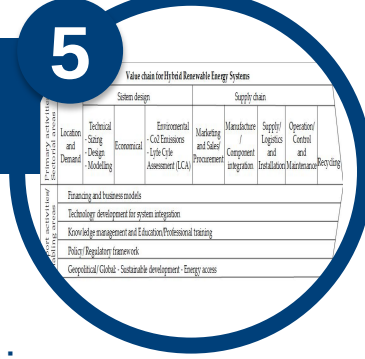
Enabling areas and support activities (in horizontal)are:

- Financing and business models.
- Technology development for system integration.
- Knowledge management and Education/Professional training.
- Policy/Regulatory framework.
- Geopolitical/Global: Sustainable Development, Energy Access.

Financing/ Business model	Knowledge management/ Education	Policy/ Regulatory framework	Sustainable development	Energy access
6	2	15	20	12
[95] [82] [11] [85] [119] [118]	[71] [70]	[123] [76] [121] [80] [73] [125] [126] [71] [88] [122] [82] [65] [128] [127] [124]	[74] [95] [123] [104] [76] [137] [73] [7] [52] [72] [140] [88] [122] [82] [79] [14] [13] [85] [128] [48]	[54] [51] [55] [125] [75] [126] [138] [139] [141] [118] [10] [36]

Knowledge management, education and training- closing the gap

+ Integration
Value Chain



- Global challenges require global solutions and knowledge based sectors require knowledge management and stakeholders cooperation.

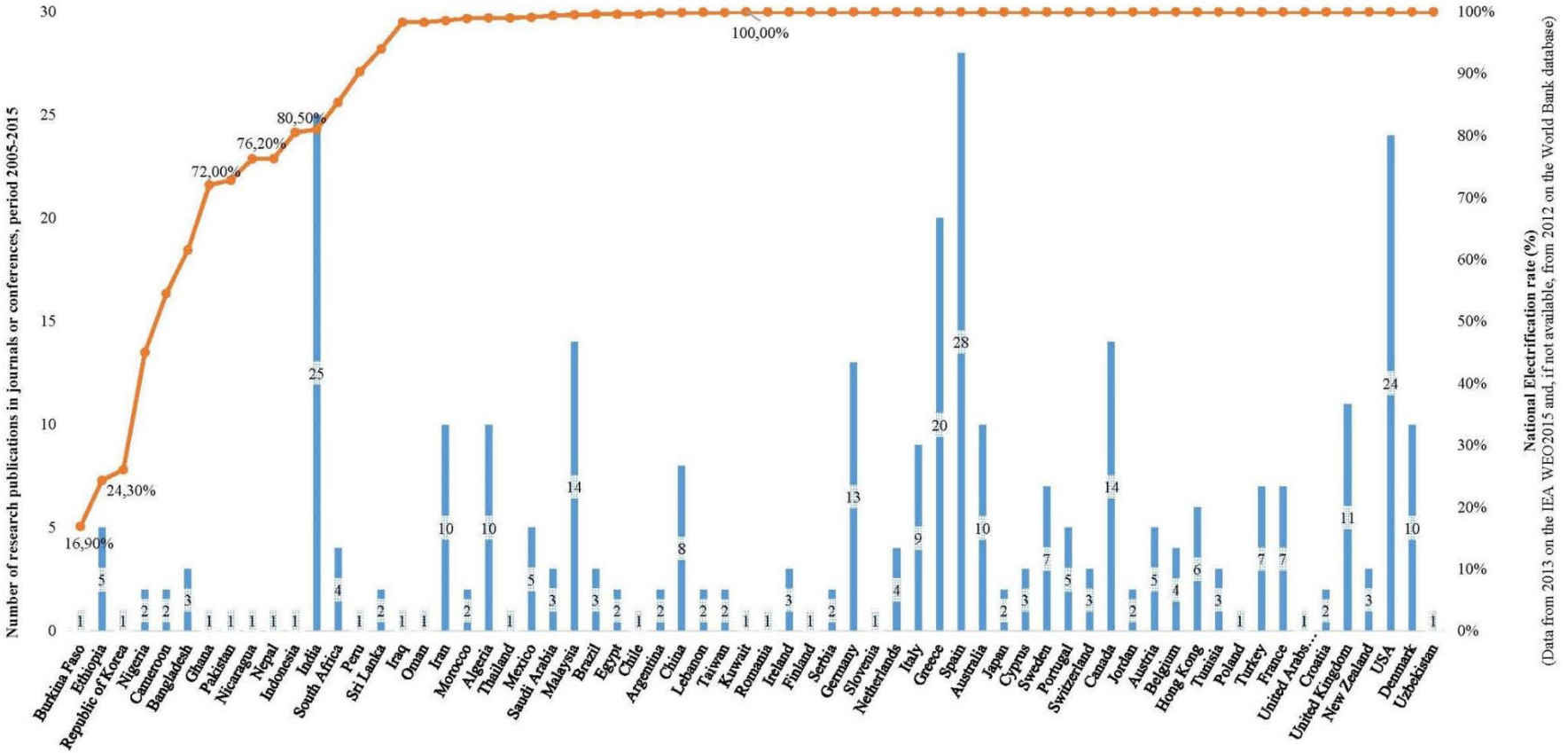
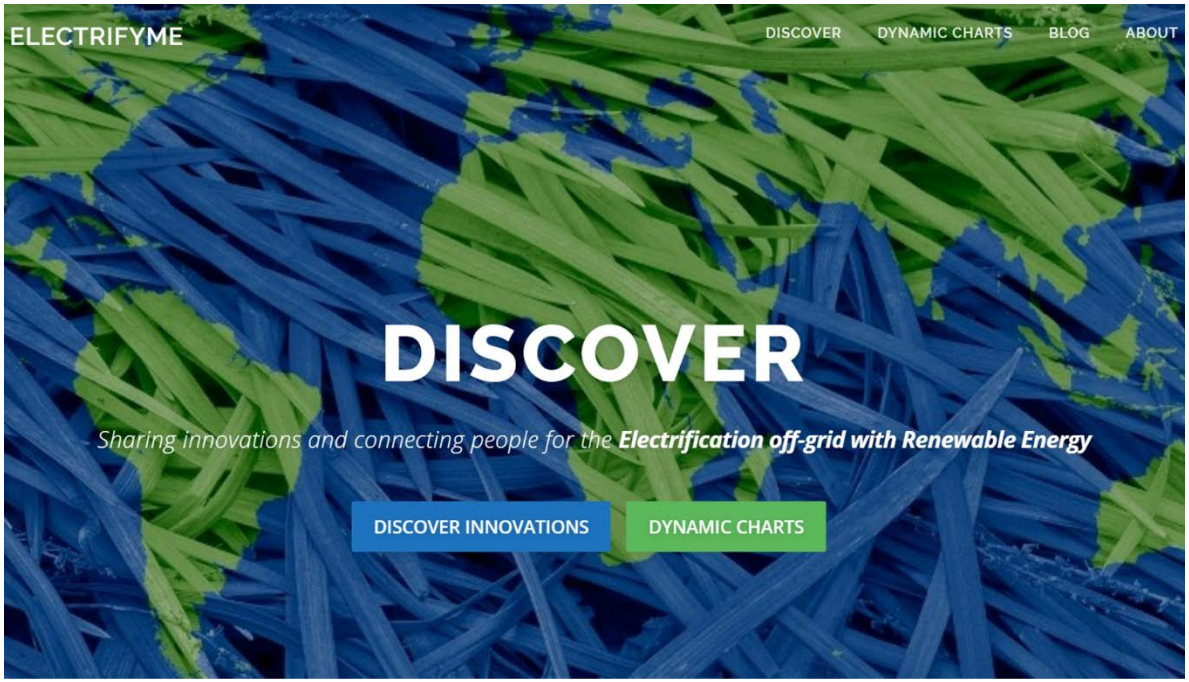


Figure 3.8: Number of research publications identified and ordered by the national electrification rate (%)

+ Multidisciplinarity- www.Electrifyme.org

(Knowledge transfer & valorization)

- The main objective of the ElectrifyMe website initiative via www.electrifyme.org is to foster future multi-disciplinary research in stand-alone HRES while sharing the developments and findings during this work.



-> "Discover" page: sharing the detailed list of innovations.

-> "Dynamic charts" page: visualizing main selection criteria: publishing country, thematic focus and year.

"Discover" page
- detailed list of innovations

+ Multidisciplinarity

www.Electrifyme.org

(Knowledge transfer & valorization)

ELECTRIFYME

DISCOVER DYNAMIC CHARTS BLOG

What are the challenges in your country for the electrification off-grid with renewable energy?

Discover in the table the innovations about it

Country	Year	Thematic ..	Energy sources	Title
Algeria	2013	Sizing	PV/ Diesel	Optimal Sizing of a Stand-alone Photovoltaic System with Energy Management in Isolated Areas
	2012	Not specified	Not specified	Feasibility study of hybrid Diesel–PV power plants in the southern of Algeria: Case study on AFRA power plant
	2011	Not specified	Not specified	Economic and environmental analysis for grid-connected hybrid photovoltaic-wind power system in the arid region
				Sizing optimization of grid-independent hybrid photovoltaic/wind power generation system
				Techno-economic valuation and optimization of integrated photovoltaic/wind energy conversion system
	2008	Modelling	PV/ Wind/ Diesel	Contribution à l'étude théorique du comportement d'un système hybride (éolienphotovoltaïque-diesel) de production ..
		Not specified	Not specified	Sizing of stand-alone photovoltaic..
				Techno-economical study of hybrid power system for a remote village in Algeria
Argentina	2012	Energy Access	PV/ Wind/ Diesel	Argentina: Project for Renewable Energy in Rural Markets (PERMER
	2001	Policy and Re..	Not specified	Reform of the Electric Power Sector In Developing Countries: Case Study of Argentina
Australia	2014	Not specified	PV	Small-scale portable photovoltaic-battery-LED systems with submersible LED units to replace kerosene-based artisa..
	2013	Not specified	Not specified	Review of transmission schemes and case studies for renewable power integration into the remote grid
	2012	Not specified	Not specified	Criteria for Emerging Telecom and Data Center Powering Architectures
				Developing renewable energy supply in Queensland, Australia: A study of the barriers, targets, policies and actions
				Hybrid Power System Model How to get the most from your System
	2011	Not specified	Not specified	A feasibility study of hybrid wind power systems for remote communities
	2009	Not specified	Not specified	When will fossil fuel reserves be diminished?
	2008	Not specified	Not specified	Feasibility analysis of stand-alone renewable energy supply options for a large hotel
				How carbon credits could drive the emergence of renewable energies
				Solar photovoltaic (PV) on atolls: Sustainable development of rural and remote communities in Kiribati
Austria	2012	Not specified	Not specified	Legitimizing research, technology and innovation policies for transformative change: Combining insights from innovat..
	2011	Not specified	Not specified	Efficiency and effectiveness of promotion systems for electricity generation from renewable energy sources – Lesson..
	2010	Not specified	Not specified	Lessons for low-carbon energy transition: Experience from the Renewable Energy and Energy Efficiency Partnership..
	2008	Not specified	Not specified	Potentials and prospects for renewable energies at global scale
	2007	Not specified	Not specified	A guide to life-cycle greenhouse gas (GHG) emissions from electric supply technologies
Bangladesh	2012	Not specified	Not specified	Hybrid energy system for St. Martin Island, Bangladesh: An optimized mode
	2011	Not specified	Not specified	Greenhouse gas emission and renewable energy sources for sustainable development in Bangladesh
	2010	Not specified	Not specified	Prospect of wind–PV-battery hybrid power system as an alternative to grid extension in Bangladesh
Belgium	2013	Not specified	Not specified	Review of primary control strategies for islanded microgrids with power-electronic interfaces
	2012	Sizing	PV/ Grid	An autonomous photovoltaic system sizing program for office applications in Africa
	2010	Not specified	Not specified	Renewable energy costs, potentials, barriers: Conceptual issues

Year: (Todos)

Country: (Todos)

Thematic focus: (Todos)

Energy source: (Todos)

Search

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"Dynamic charts" page - publishing country

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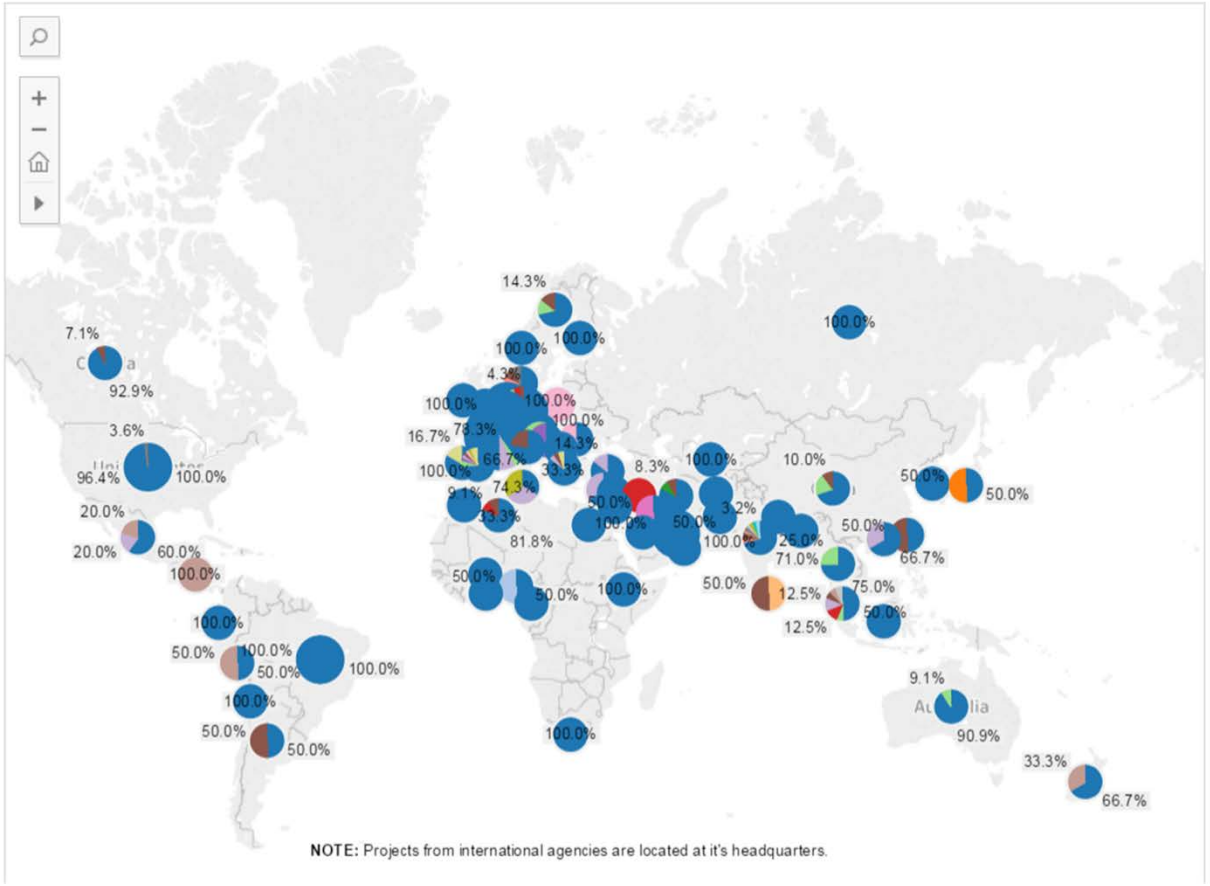
www.Electrifyme.org

(Knowledge transfer & valorization)

Publishing Country | Thematic Focus | Yearly Trend



"Dynamic charts" page - thematic focus and year

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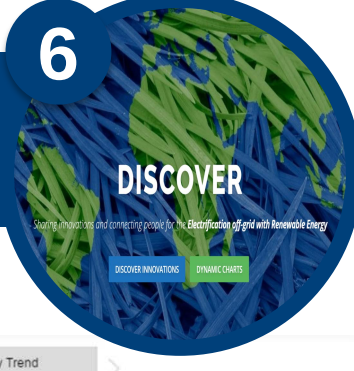
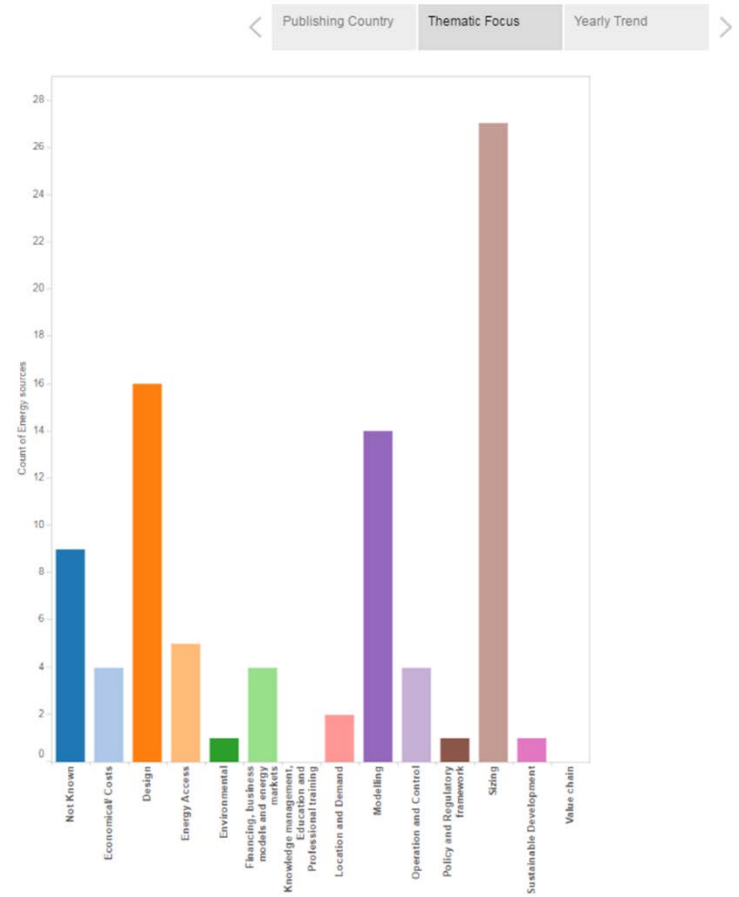
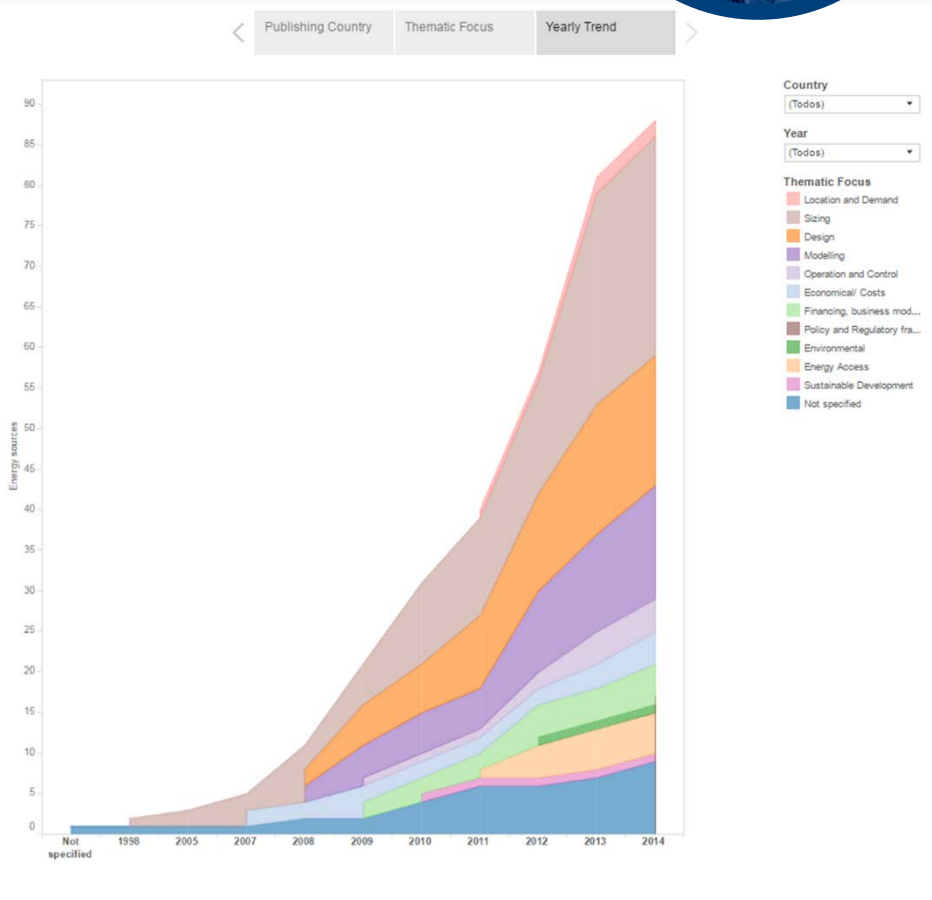
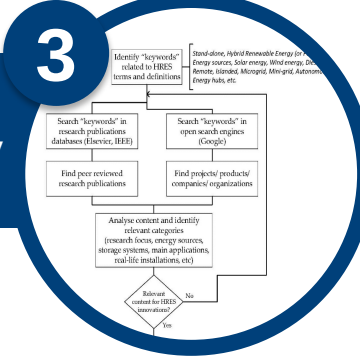






“Source identification” - type of publication

Scanning Innovations
The Research community
(Methodology & Mapping of findings)



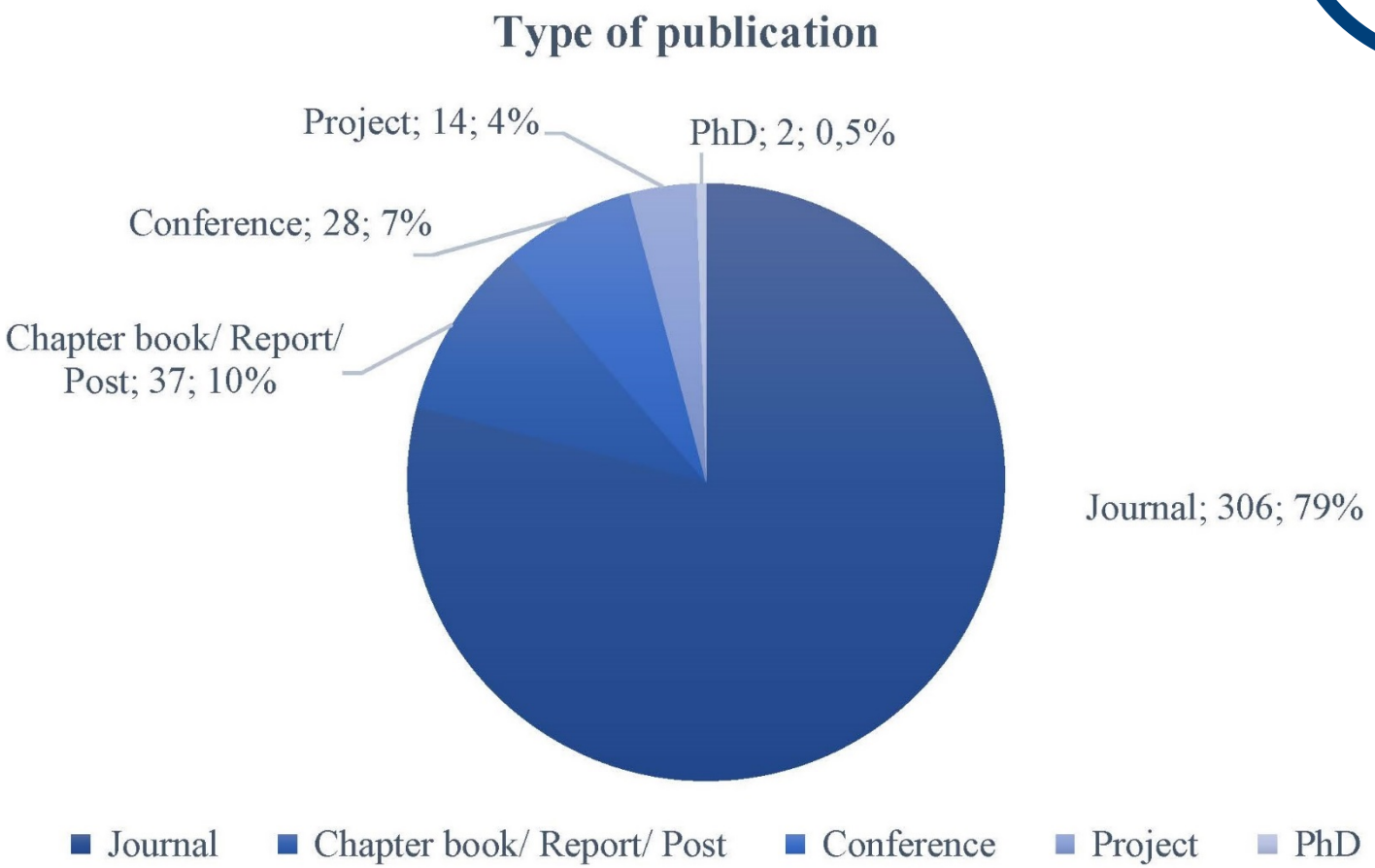
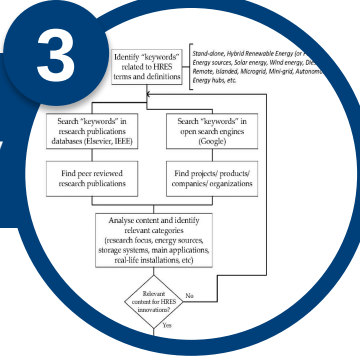


Figure 3.2: Number of publications per types (total 387)

“Source identification” - year of publication

Scanning Innovations
The Research community
(Methodology & Mapping of findings)



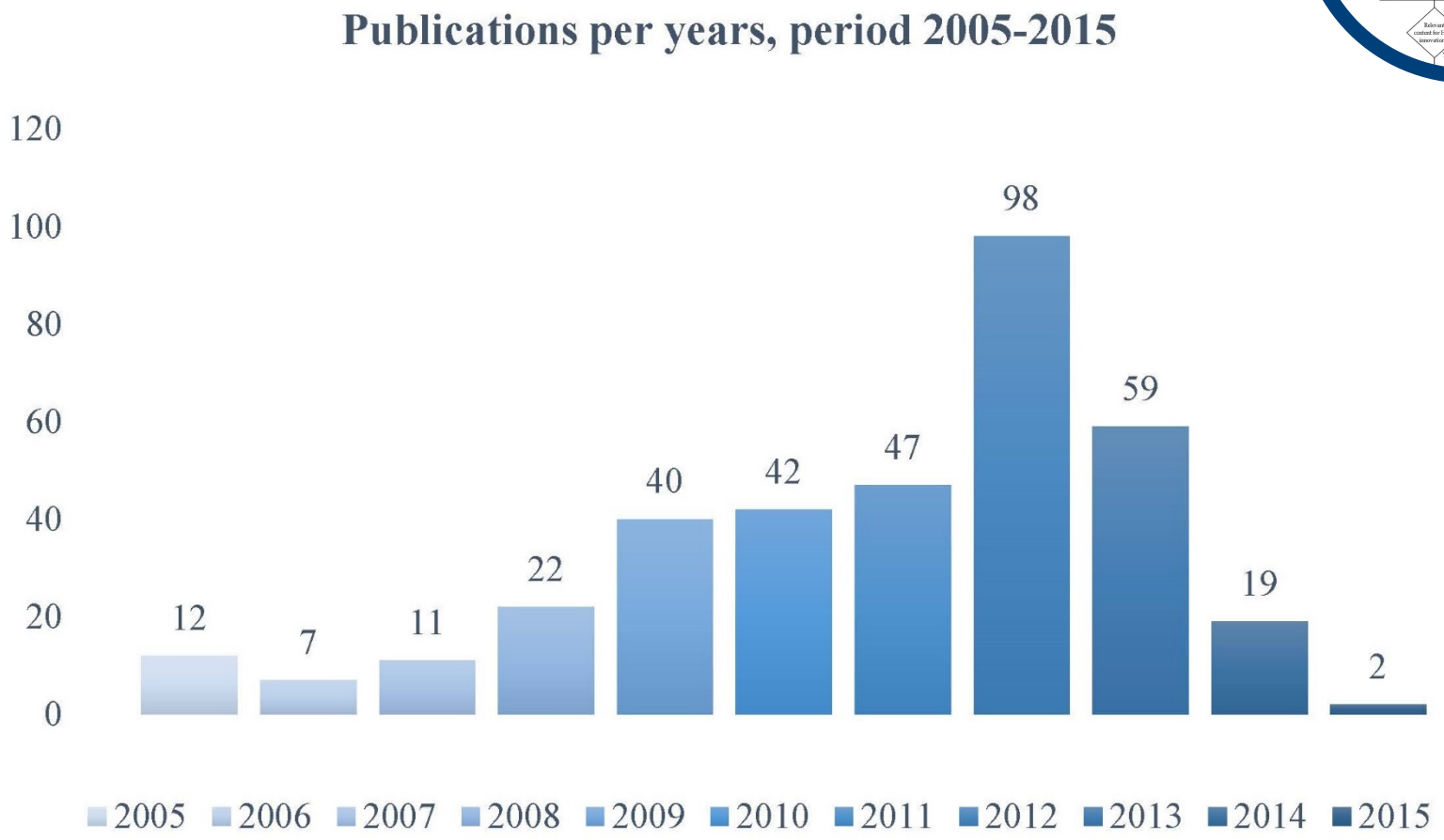
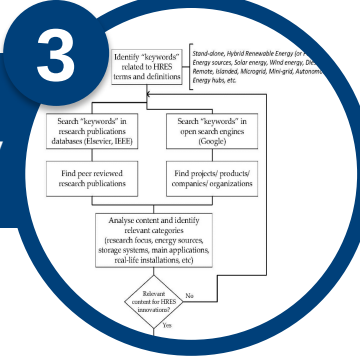


Figure 3.3: Number of publications per years, during the period 2005-2015 (total 359)

“Source identification” - Top 10 journals

Scanning Innovations
The Research community
(Methodology & Mapping of findings)



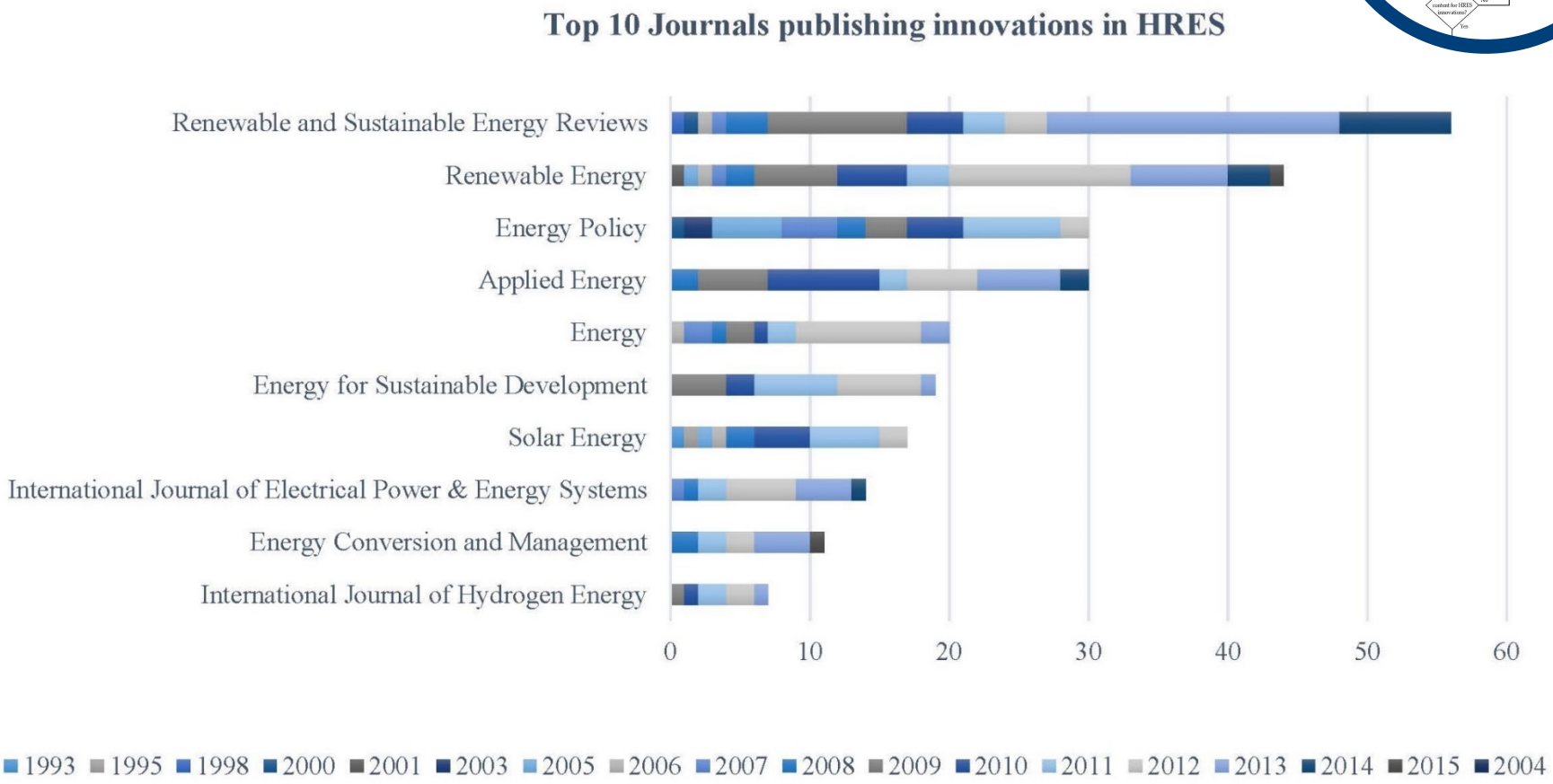
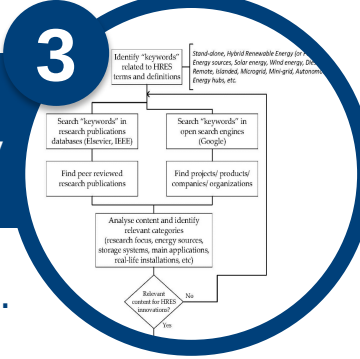


Figure 3.4: Top 10 journals publishing innovations in HRES (total 248 articles)

“Thematic focus” - Technical driven

Scanning Innovations
The Research community
(Methodology & Mapping of findings)



- **Technical focus** is devoted to half of the publications, 126 out of 265 (46%).
- **Economical focus** is also widely present, as in 56 publications.
- **Environmental focus** is little present.
- **Other aspects** that are highly present in the publications of innovations in HRES, with 68 publication so 26%, e.g.: education, policy, sustainable development, and energy access.

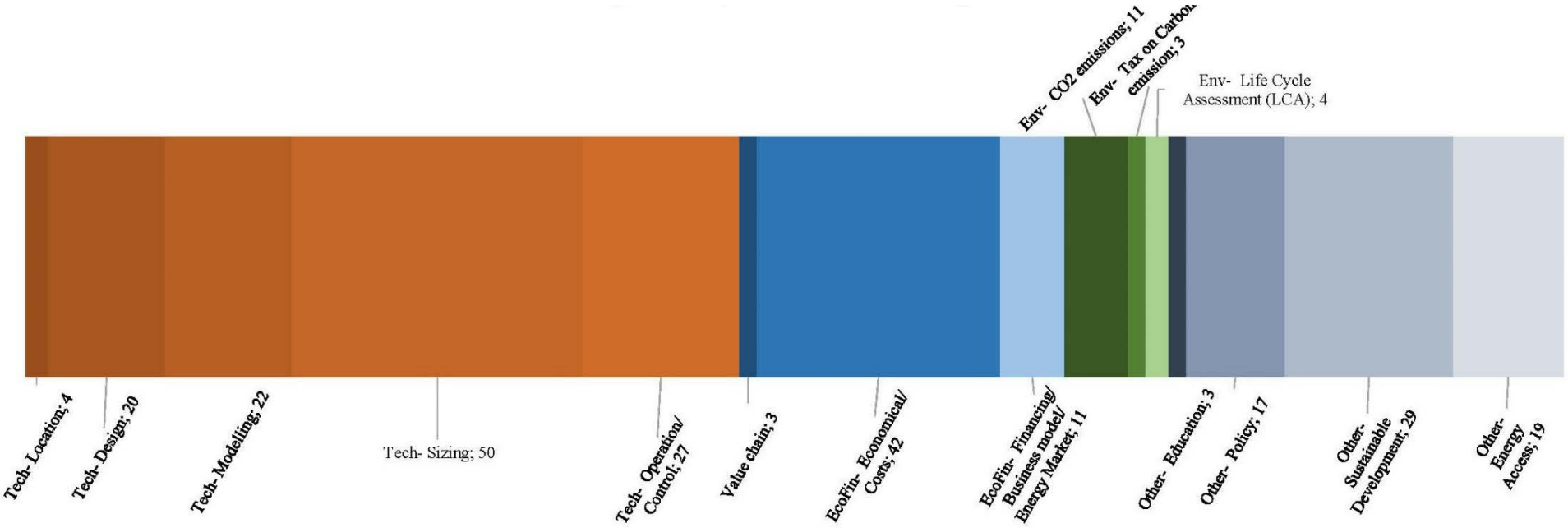
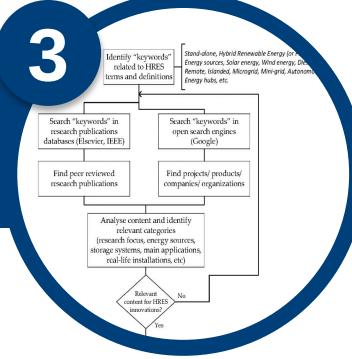


Figure 3.20: Thematic focus of research publications related to technical, economic, environmental and other aspects (total 265 publications)

“Thematic focus”
- increase other aspects

Scanning Innovations
The Research community
(Methodology & Mapping of findings)



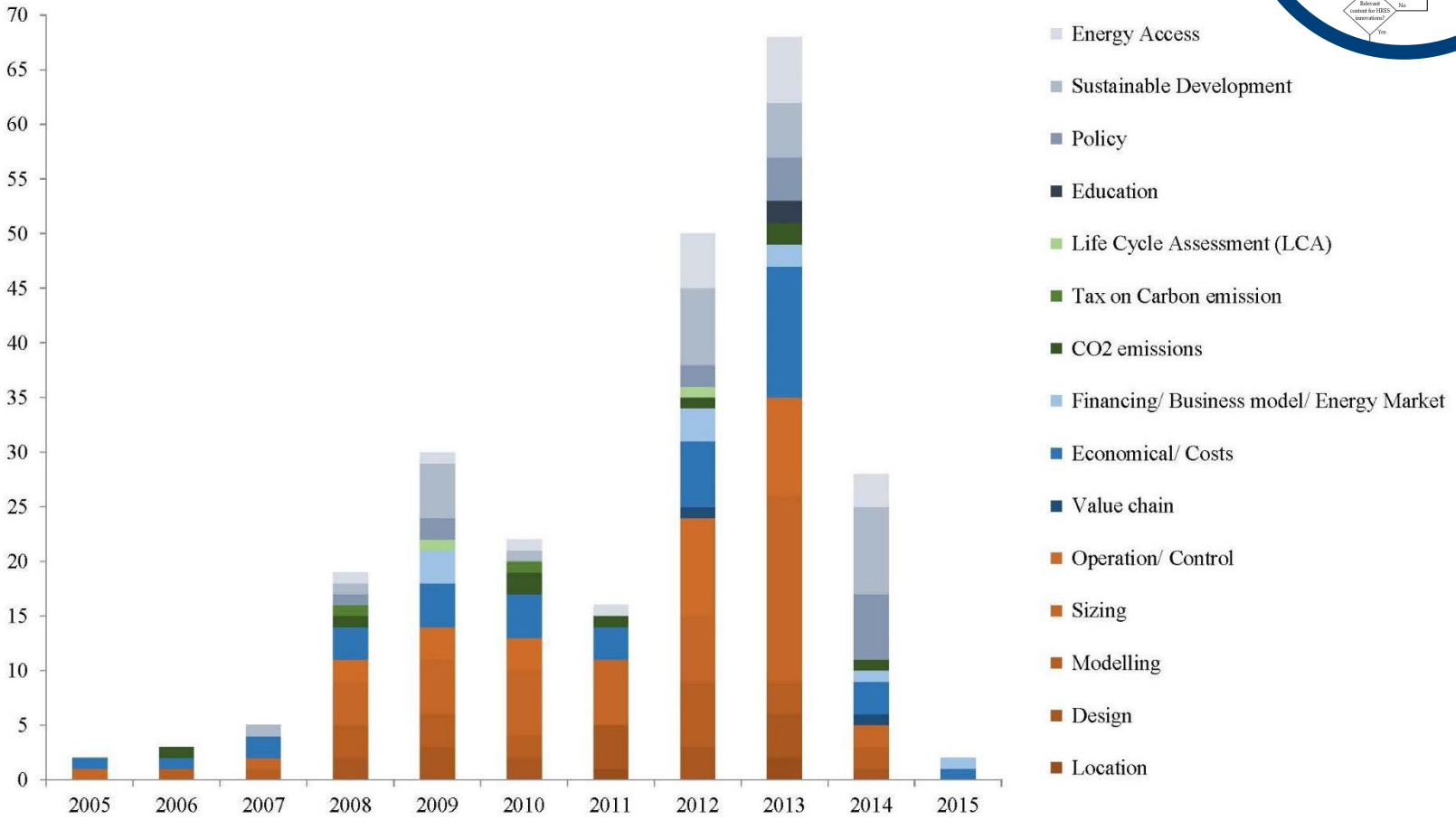
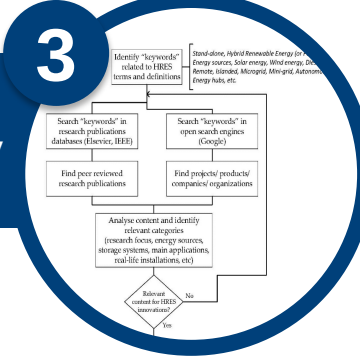


Figure 3.21: Thematic focus of research publications related to **technical**, **economic**, **environmental** and **other aspects** (per years, period 2005 - 2015) (total 265 publications)

“Energy sources”
- Solar PV dominated

Scanning Innovations
The Research community
(Methodology & Mapping of findings)



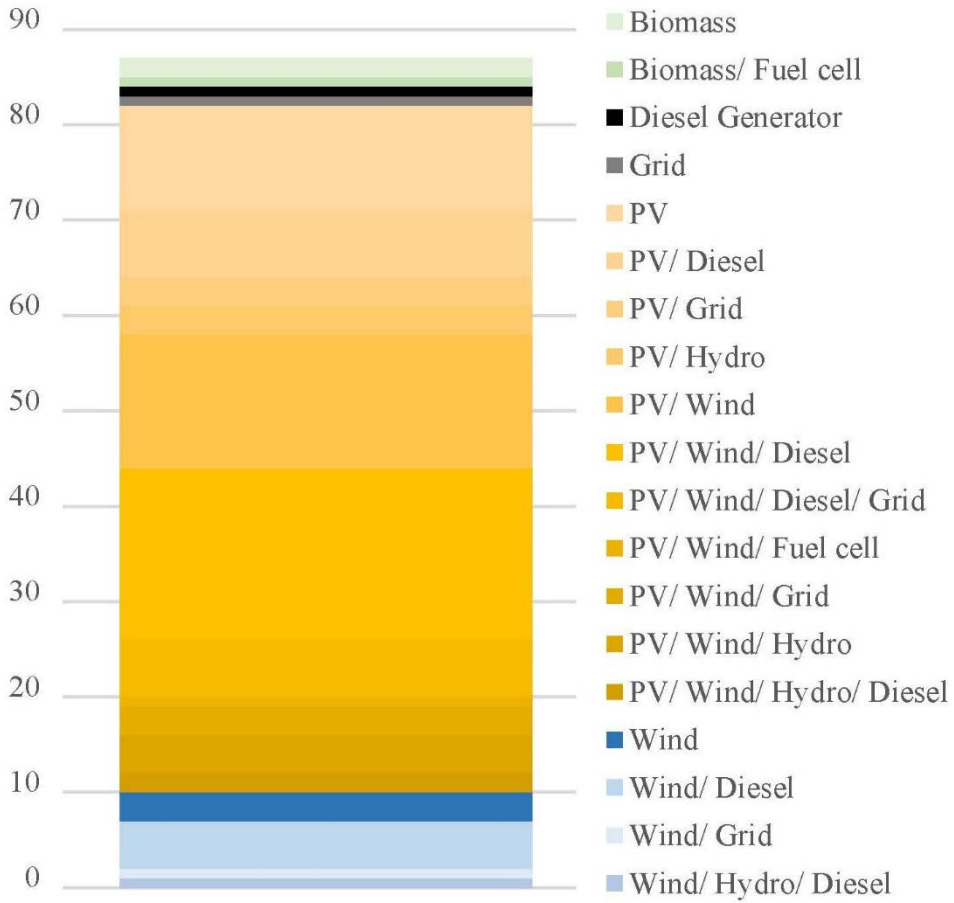
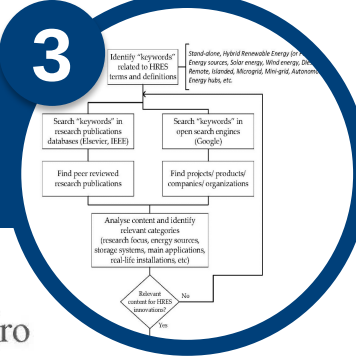


Figure 3.12: Hybrid configurations of energy sources published (total 87 publications) 2005 - 2015) (total 265 publications)

“Storage systems” - Batteries in the market

Scanning Innovations
The Research community
(Methodology & Mapping of findings)



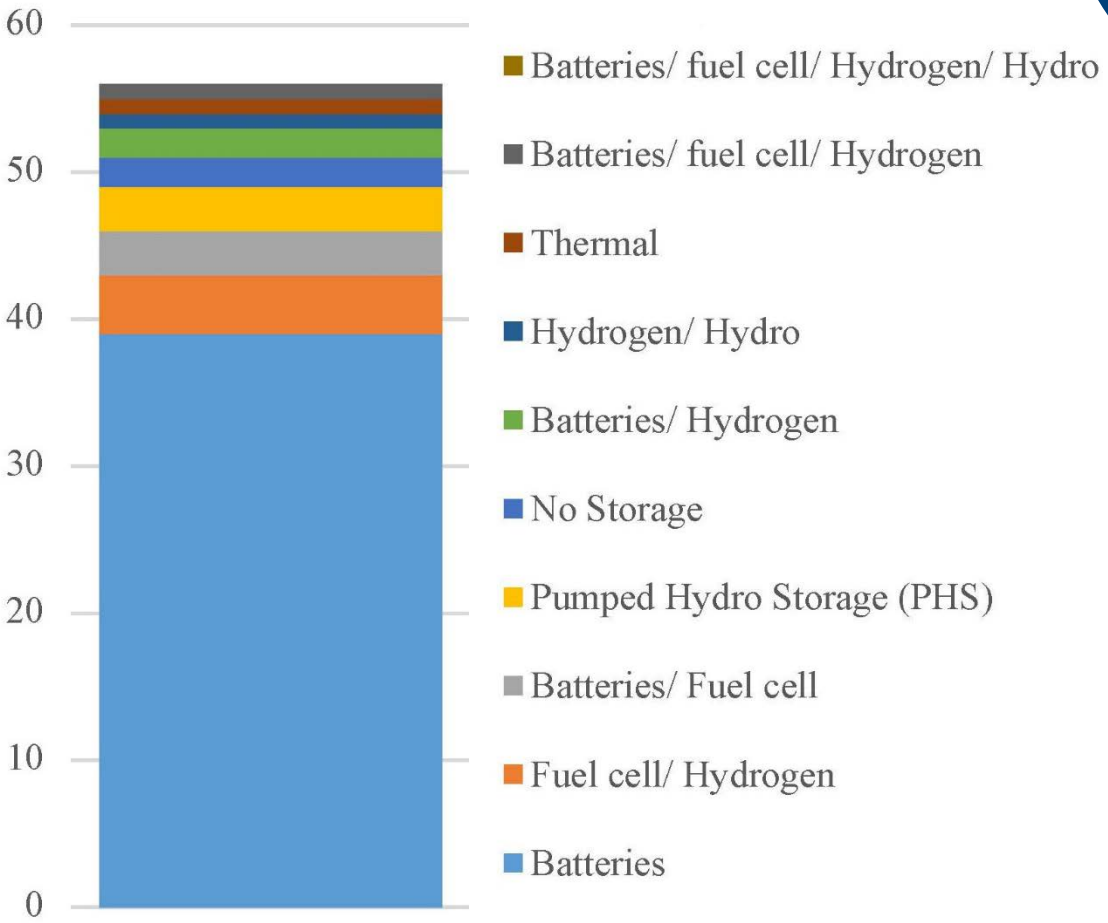
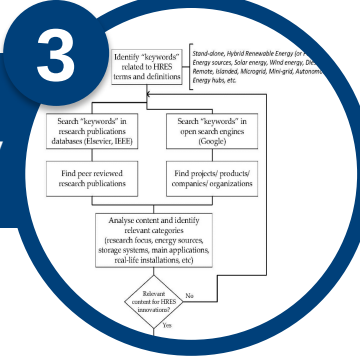


Figure 3.17: Storage systems configurations for HRES published (total 58 publications)

“Main applications” - Households, Telecom,..

Scanning Innovations
The Research community
(Methodology & Mapping of findings)



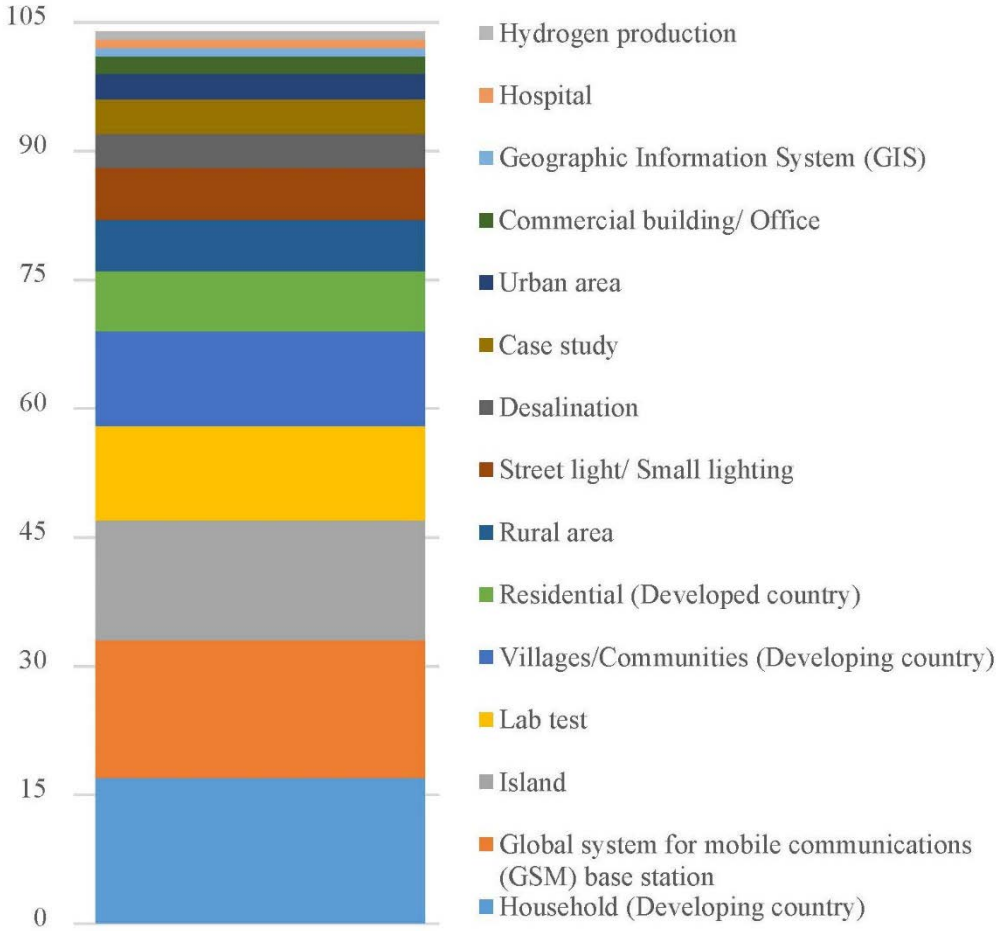


Figure 3.18: Main applications present in HRES research publications (total 104 publications)

User journey
- LEDsafari founder, India

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Message

I am the founder of LEDsafari. LEDsafari is a social start-up based in Lausanne, Switzerland that aims to assimilate clean energy & sustainable innovation education through a unique science & design training centred on … See more

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About us

LEDsafari is a social startup based in Lausanne, Switzerland that aims to teach solar technology in schools by integrating innovative pedagogy and hands-on practical training through creating a solar LED lamp.

The LEDsafari lamp is a low cost MIY (Make-it-yourself) solar lamp that uses a small solar panel (0.5 W) to convert energy from the sun, store it in a battery and use it to power an LED bulb.

Through our teachings, students learn and subsequently apply solar technology theories by assembling an electrical circuit

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ELECTRIFYME DISCOVER DYNAMIC CHARTS B

DISCOVER

What are the challenges in your country for the electrification off-grid with renewable energy?
Discover in the table the innovations about it

Country	Year	Thematic ..	Energy sources	Title
India	2014	Sizing	PV/ Wind/ Hydro/ Di..	Off-grid electricity generation with renewable energy technologies in India: An application of HOMER
	2013	Design	PV/ Wind/ Diesel	Economic analysis and power management of a ..
		Modelling	PV/ Wind/ Diesel	Solar power generation by PV (photovoltaic) technology: A review
		Not specified	Not specified	Potential impacts of emission concerned policies on power system operation with renewable energy sources
	2012	Financing, bu..	PV/ Grid	Techno-economic Evaluation of the Feasibility of a Smart Street Light System: A case study of Rural India
		Not specified	Not specified	An Optimal Stand-Alone Biomass/SolarPV/Pico-Hydel Hybrid Energy System..
				Optimal design of hybrid PV–diesel–battery system..
				Power flow management algorithm for photovoltaic systems feeding DC/AC loads
				Rural electrification: Optimising the choice between decentralised renewable energy sources and grid extension
	2011	Not specified	Not specified	Off-grid rural electrification experiences from South Asia: Status and best practices
				Proportional–integral controller based small-signal analysis of hybrid distributed generation systems
			Wind	Reliability analysis of wind embedded power generation system for Indian Scenario
	2010	Design	PV/ Wind/ Diesel/ Gr..	A current and future state of art development of hybrid energy system using wind and PV-solar: A review
		Not specified	Not specified	Assessment and evaluation of PV based decentralized rural electrification: An overview
				Design of isolated renewable hybrid power systems
				Optimal hybrid renewable energy..
		Sizing	Wind/ Grid	PROFIT MAXIMIZATION AND OPTIMAL SIZING OF RENEWABLE ENERGY SOURCES IN A HYBRID SYSTEM
	2009	Not specified	Not specified	A current and future state of art development of hybrid energy system using wind and PV-solar: A review
				Energy, economics and environmental impacts of renewable energy systems
				Optimal Operation of Biomass/Wind/PV..
	2007	Economical/ ..	PV/ Wind/ Hydro	Optimised model for community-based hybrid energy system
		Not specified	Not specified	A review of wind energy technologies
	2006	Not specified	Not specified	A review of energy models
	1998	Sizing	Wind/ Hydro/ Diesel	Effect of wind energy system performance on optimal renewable energy model—an analysis

Year
(Todos)

Country
India

- ✓ India
- Indonesia
- Iran
- Iraq
- Ireland
- IRENA
- Italy
- Japan
- Jordan
- Kuwait
- Lebanon
- Malaysia
- Mexico
- Morocco
- Nepal
- Netherlands
- New Zealand
- Nicaragua
- Nigeria
- Norwey
- NREL
- OECD

User journey
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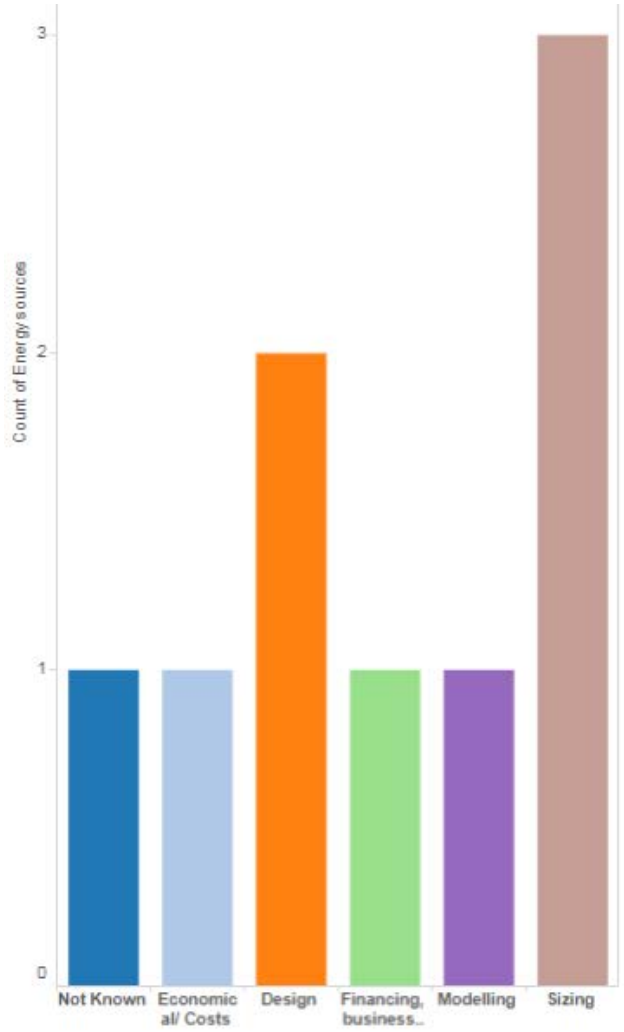

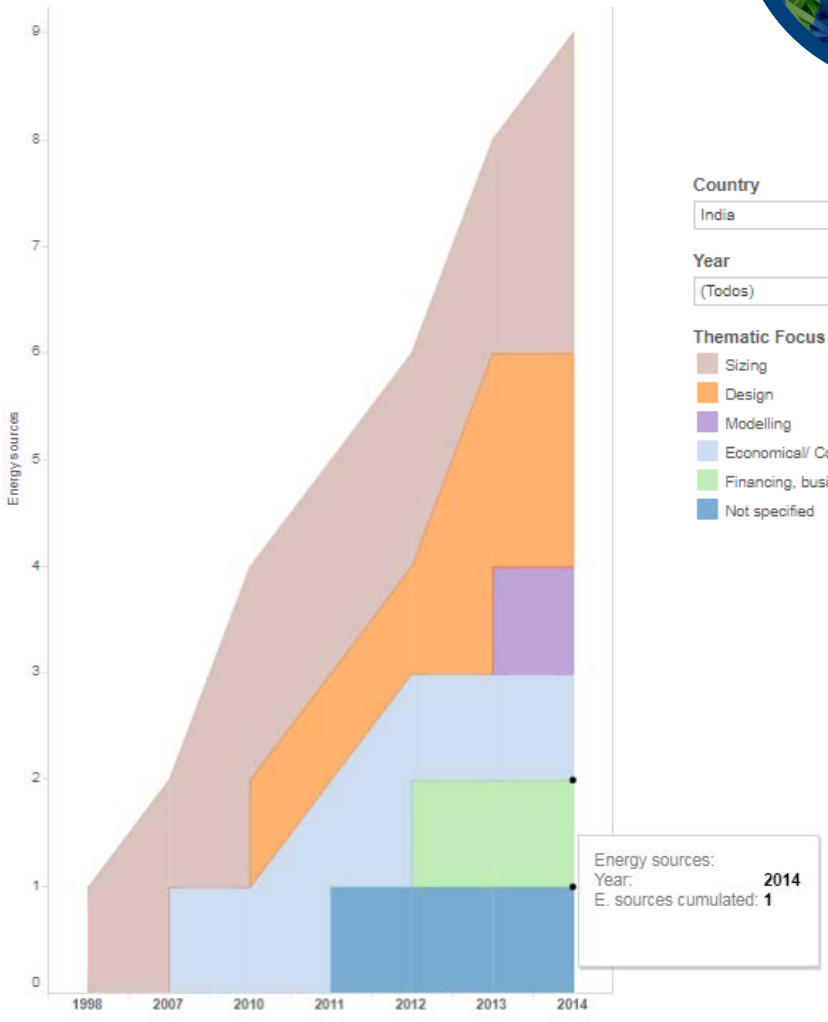

User journey
- LEDsafari founder, India

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DISCOVER

What are the challenges in your country for the electrification off-grid with renewable energy?
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		Not specified	Not specified	Potential impacts of emission concerned policies on power system operation with renewable energy sources
	2012	Financing, bu..	PV/ Grid	Techno-economic Evaluation of the Feasibility of a Smart Street Light System: A case study of Rural India
		Not specified		

Year
(Todos)
Country
India
Thematic focus

Financing, business models and energy markets

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Techno-economic Evaluation of the Feasibility of a Smart Street Light System: A case study of Rural India

Nagendra R Velaga, Amit Kumar

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Abstract

Throughout the world application of vehicle and infrastructure based intelligent transportation systems have been increased over the last decade. Most of these advanced intelligent

Other users
- companies, public bodies

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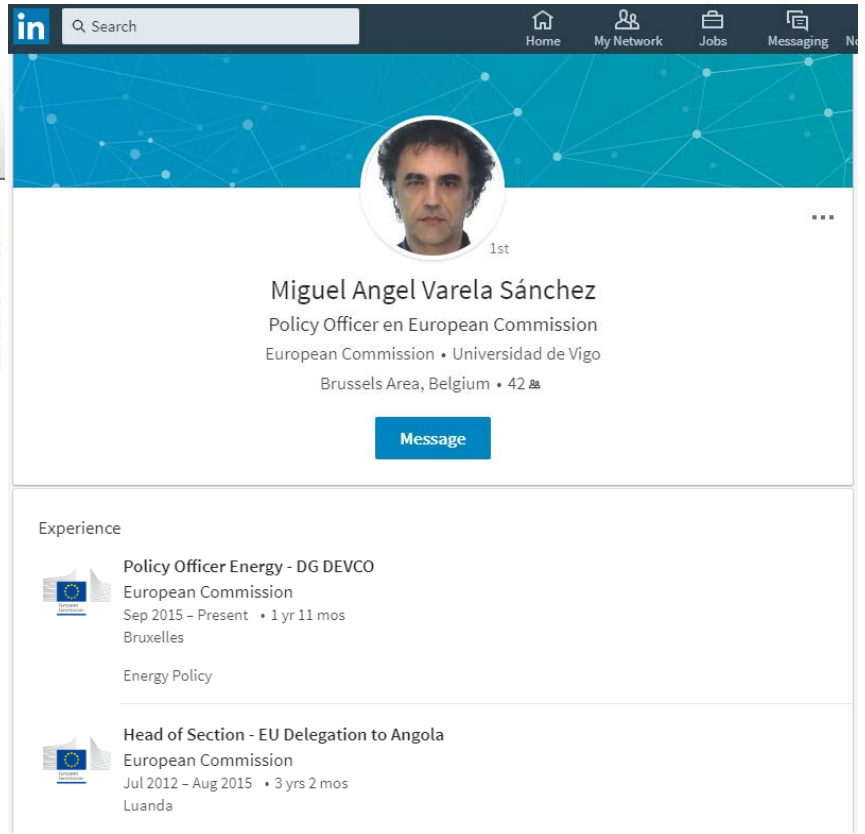
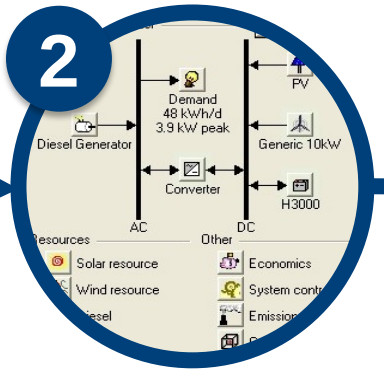


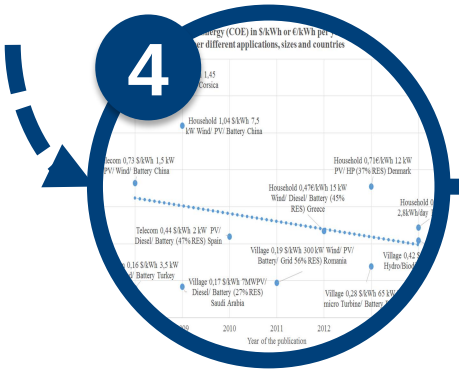
Energy Poverty
The Problem

Renewables Off-grid
The Challenge

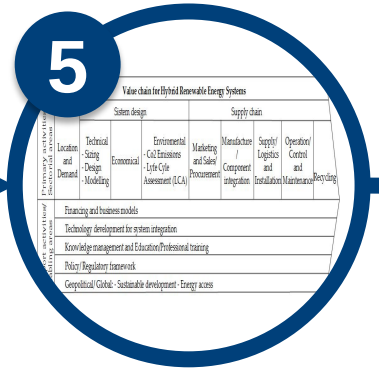


Design criteria
The Study case

Scanning Innovations
The Research community



Design of HRES
Beyond economic criteria



+ Integration
Value Chain

+ Multidisciplinarity
www.Electrifyme.org
(Knowledge transfer & valorization)

Main contributions
So, what next?
(Conclusions & Future work)

ElectrifyMe.org:
Research studies, trends and opportunities for researcher's community integrating renewables off-grid

Mar Martínez-Díaz

mar.martinez@esat.kuleuven.be

Director:
Prof. dr. ir. Johan Driesen (KU Leuven/ Energyville)
johan.driesen@esat.kuleuven.be

Department:
Electrical Engineering (ESAT-Electa, KU Leuven)