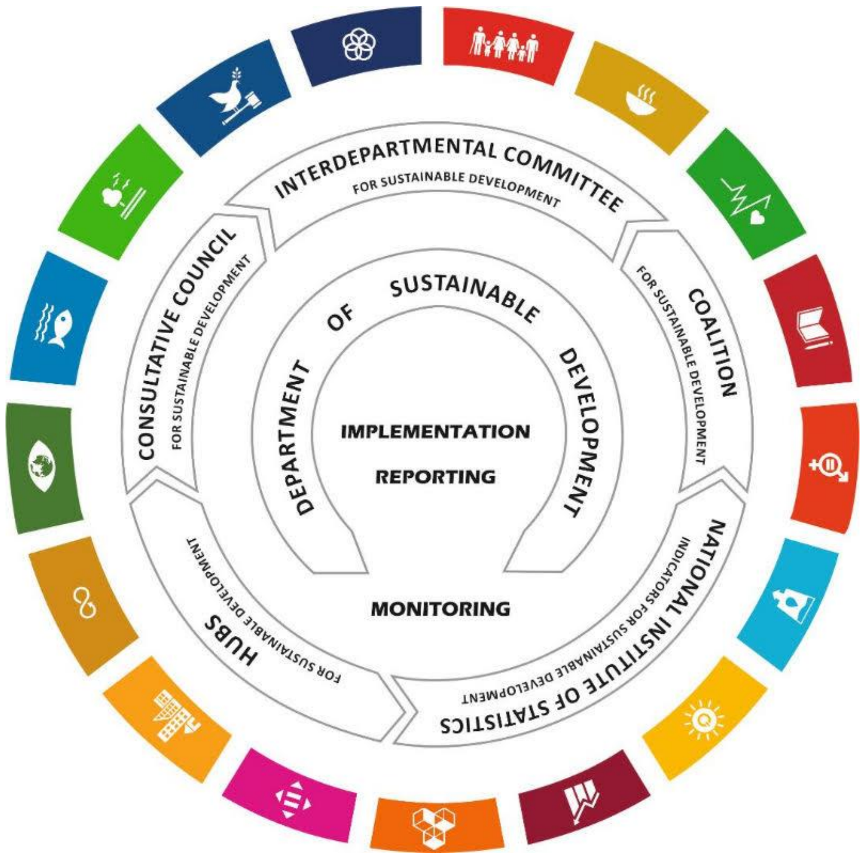
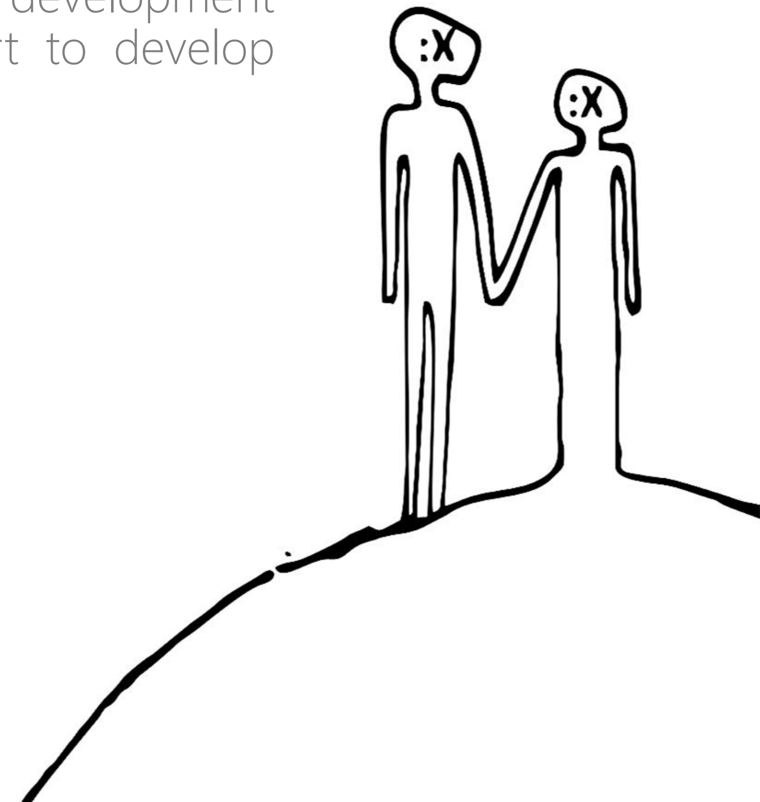
DEPARTMENT OF
SUSTAINABLE DEVELOPMENT

Research and Innovation for a sustainable development



"The promotion of sustainable development will require an organized effort to develop and diffuse new technologies ..."

Our Common Future
Oxford University Press, 1987



Prof.Dr. Ionut Purica

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Content

Research and Innovation for a sustainable development

- Equipment ALFRED SMR
- System support energy storage
- Big data evaluation of climate change risk events circular economy and smart cities
- Modeling energy systems evolution MESSAGE
- Discusions

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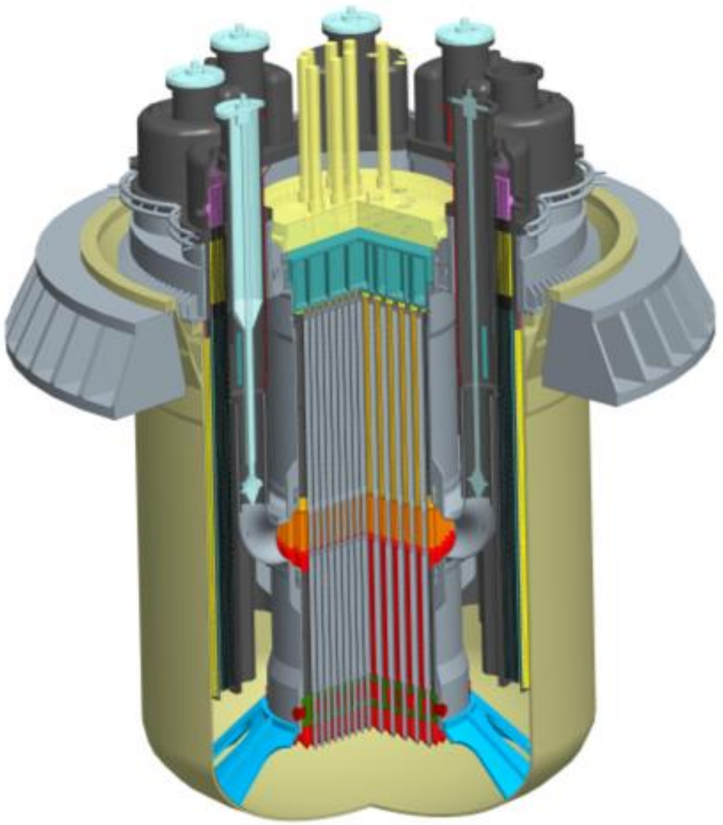
Equipment ALFRED SMR

Romanian Nuclear Power

- R&D – support for CANDU technology (operation, RWM, nuclear equipment, new fuels)
- R&D- new technologies: ALFRED (LFR) + efforts for new material development
- R&D – knowledge management – capture, storage and transfer to new generations
- Education and Training activities

What is ALFRED?

Advanced **L**ead **F**ast **R**eactor **E**uropean **D**emonstrator



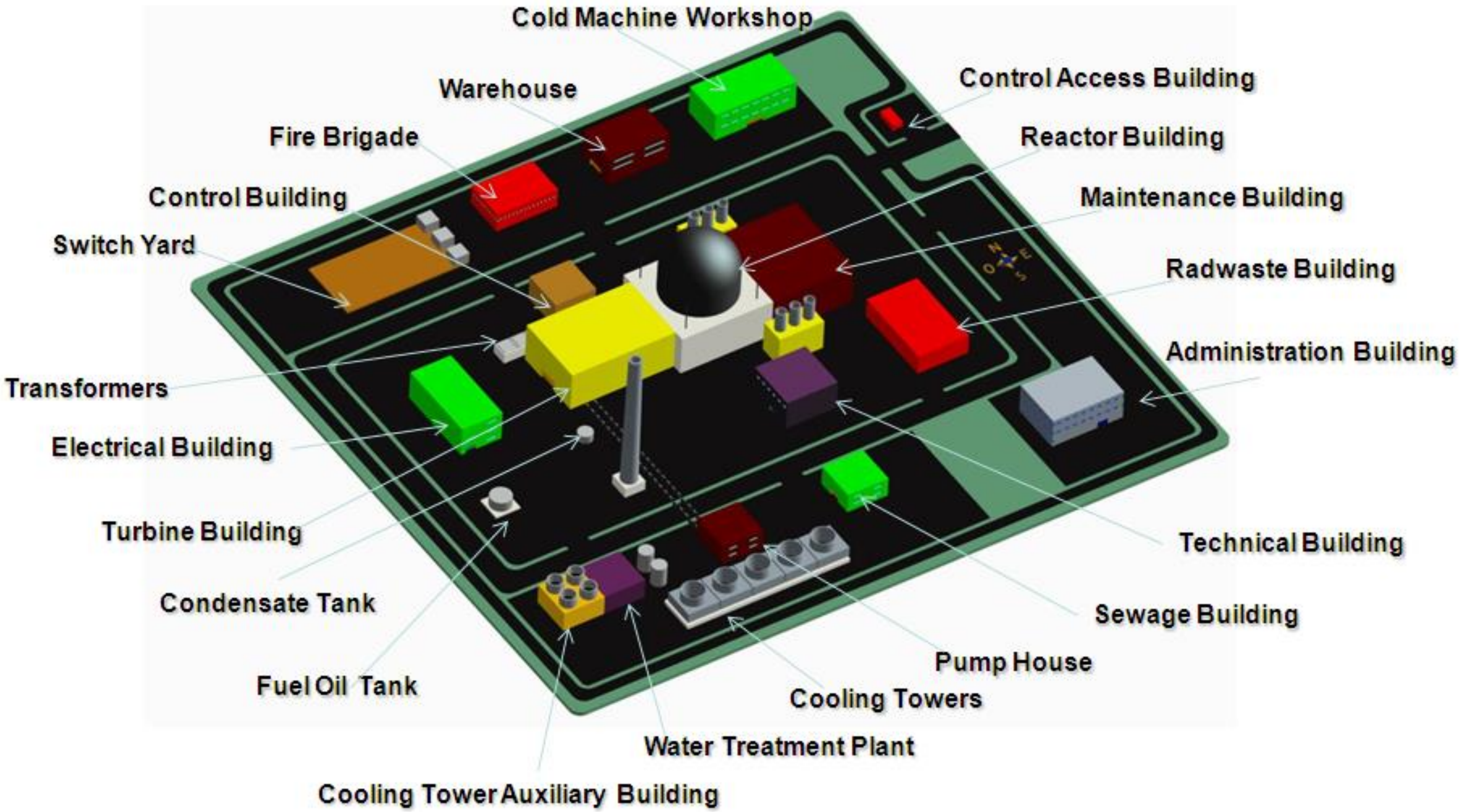
ALFRED is a Research Reactor, as part of a **pan-European Distributed Research Infrastructure**.

ALFRED is a **demonstrator**, and not a prototype, dedicated to the **development** of the LFR technology.

ALFRED is a 300 MWth **reactor** addressing the concerns on **safety**, **economics** and **sustainability** of nuclear energy.

Demonstration of a safer and more sustainable secure energy

ALFRED = investment of 1 billion Euro + 0.3-0.5 for preparatory phase



ALFRED is supported at international level

SNETP
SUSTAINABLE NUCLEAR ENERGY TECHNOLOGY PLATFORM

http://www.snetp.eu/esnii/

ESNII Task Force

GEN IV International Forum

https://www.gen-4.org/gif/jcms/c_9260/Public

From FPs to H2020

http://ec.europa.eu/programmes/horizon2020/en

- Major investments in EU
- Ongoing projects under FP7
- Proposals for H2020

National Programmes

CooA with ROSATOM

Preparing Today for Tomorrow's energy needs

The FALCON Consortium

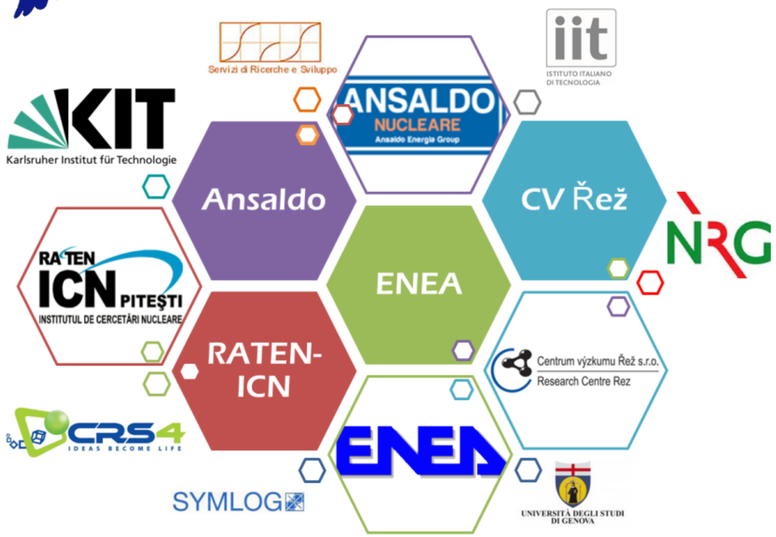
Signature Ceremony, Dec. 18 2013

PHASE 1

- 18 months
- Unincorporated consortium
- In-kind contributions
- Optimize the cooperation
- Areas: strategic, management, governance, financial and technical

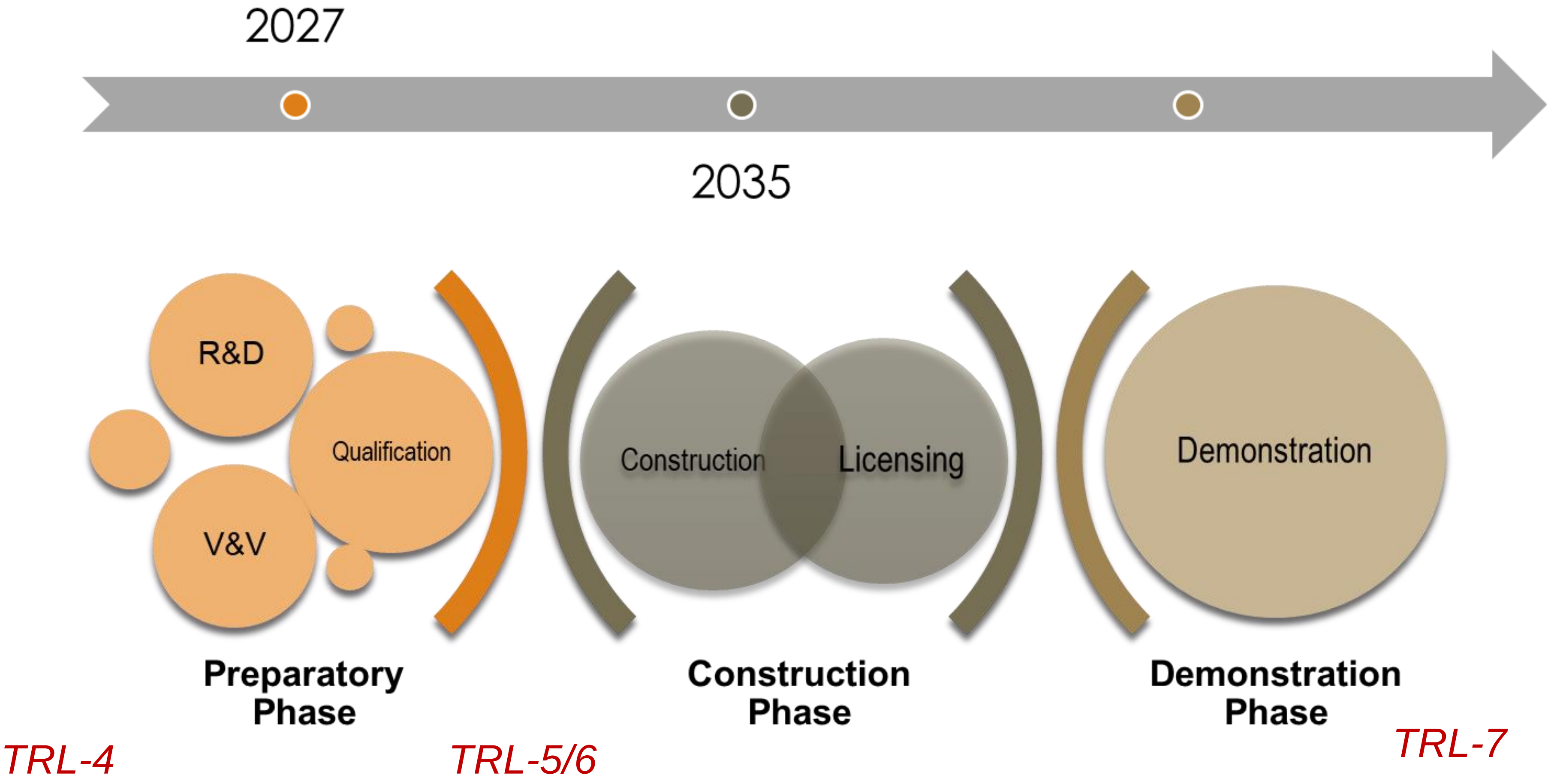
PHASE 2

- Detailed agreement
- Manage the R&D needs
- Engineering design
- Licensing, and
- Commit the construction



Sharing a common vision for achieving the objectives

ALFRED DEMONSTRATION will START in 2035



Improving the Technology Readiness Level (TRL)

ALFRED Project– Social Impact

Benefits for Romanian society:

- implementation of a high technology and **consolidation of the position of the country in the nuclear sector**, including also aspects derived from intellectual property and quality of the research and development
- possibility to increase **the sustainability of the use of natural resources**
- **improvement of the experimental and testing infrastructure** leading to a deep involvement of the country in Generation IV development
- **stimulation of the national research** by active involvement of the R&D organizations and industry in programmes of international interest
- contribute to the **reduction of loss of high qualified human resources and young talents** (ALFRED as an infrastructure with high interest RDI themes, international environment)
- stimulation of RDI sector, **generation of new projects and international co-operations**
- creation of **new jobs**, **stimulation of local and regional development**, strengthening of RDI poles in South-Muntenia region

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System support energy storage

Impact of the changing Energy Landscape

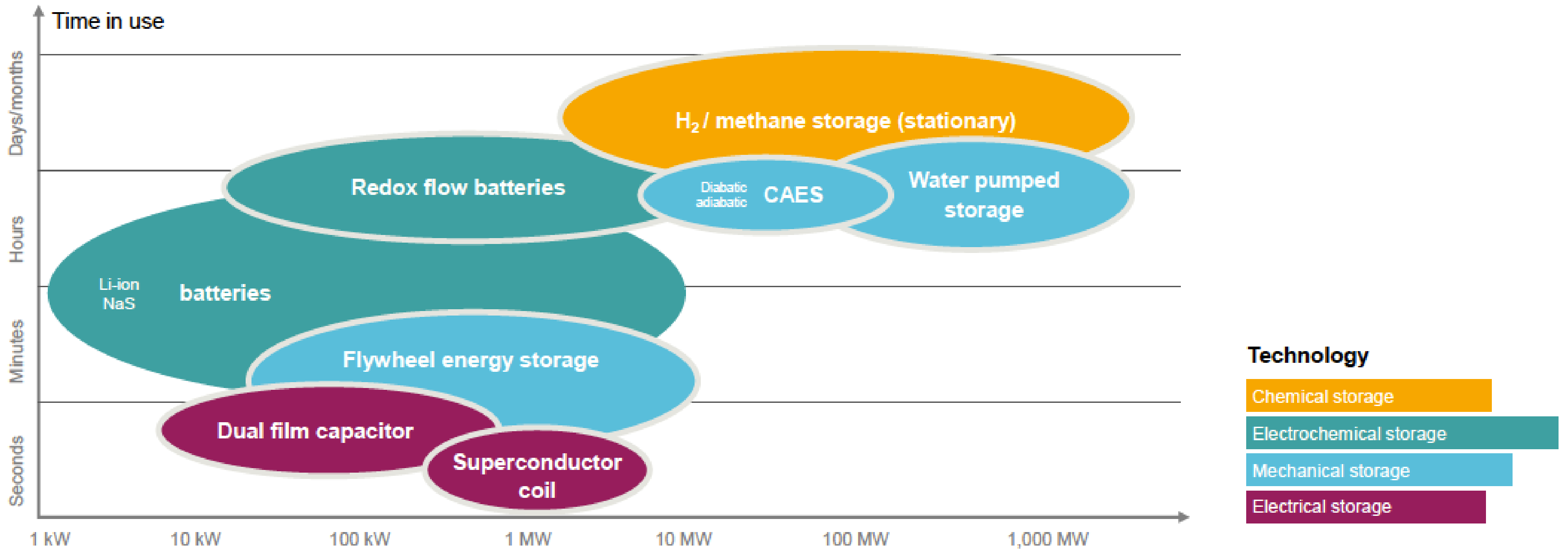
Different solutions for different market stages

<10%	20+%	40+%	60+%	80+%
Traditional mix	**System integration**	**Market integration**	**Regional autonomous system**	**Decoupled generation and consumption**
– Fossil (coal, gas, oil) – Nuclear – Renewables (mainly hydro)	– Fossil (coal, gas, oil) – Renewables (wind, PV, hydro)	– Capacity markets etc.	– Predictable regional "area generation" (topological plants)	– Interaction of all energy carriers
– Efficiency – LCC reduction – Availability / reliability / security	– Decreasing spot market prices – Subsidized economy – Increasing redispatch[1] operation	– Power2Heat, CHP increasing – Demand side management – *First storage solutions* – HVDC/AC overlay	– Regional plants, cellular grids – HVDC overlay and meshed AC/DC systems – *Power2Chem /* – Stability challenge	– Complete integration of decentralized power generation – *Storage systems/* – Return of gas power plants?
Past	**Today**	**Mid-term**		**Long-term**

1) Corrective action to avoid bottlenecks in power grid

Energy storage technologies & P2X

There is no 'silver bullet' or one solution fits all.



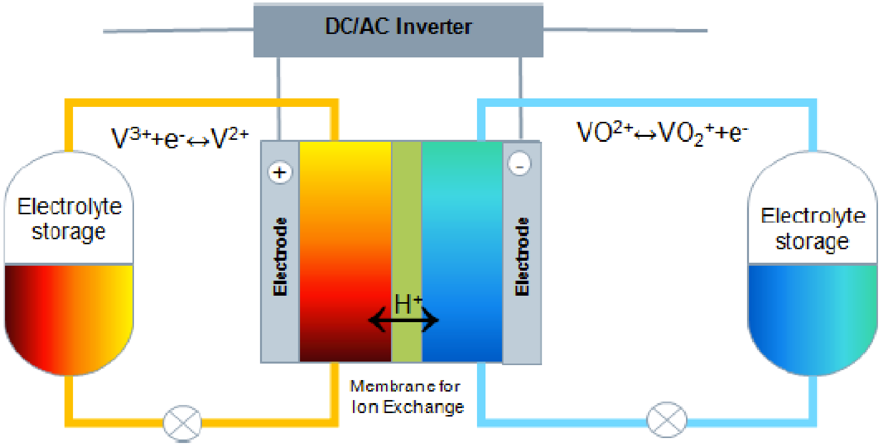
Source: Study by DNK/WEC "Energie für Deutschland 2011", Bloomberg – Energy Storage technologies Q2 2011
CAES – Compressed Air Energy Storage

Beyond Lithium-Ion
What is a Flow Battery?

A **flow battery**, or **redox flow battery** (after *reduction–oxidation*), is a type of rechargeable battery. The rechargeability is provided by two chemical components dissolved in liquids contained within the system and separated by a membrane.

The energy capacity is a function of the electrolyte volume (amount of liquid electrolyte) and the power a function of the surface area of the electrodes.

Many opportunities with different chemistries



1. **Enables long duration storage – 6 to 10 hours**
2. **Lifetime in excess of 10,000 cycles – 20 years**
3. **100% DoD possible with no degradation**

Power to X

Hydrogen is the fundamental technology for Power2Chemicals

Objectives:

- Connection to 10 MW wind-farm and local Network (20 kV).
- Develop an energy storage plant in order to provide grid services (balancing mechanisms to avoid grid bottlenecks).
- Injection in local gas grid and multi-use trailer-filling.
- New conditioning concept (ionic wet gas compressor).
- Demonstrating safe handling of hydrogen and create awareness in public, politics

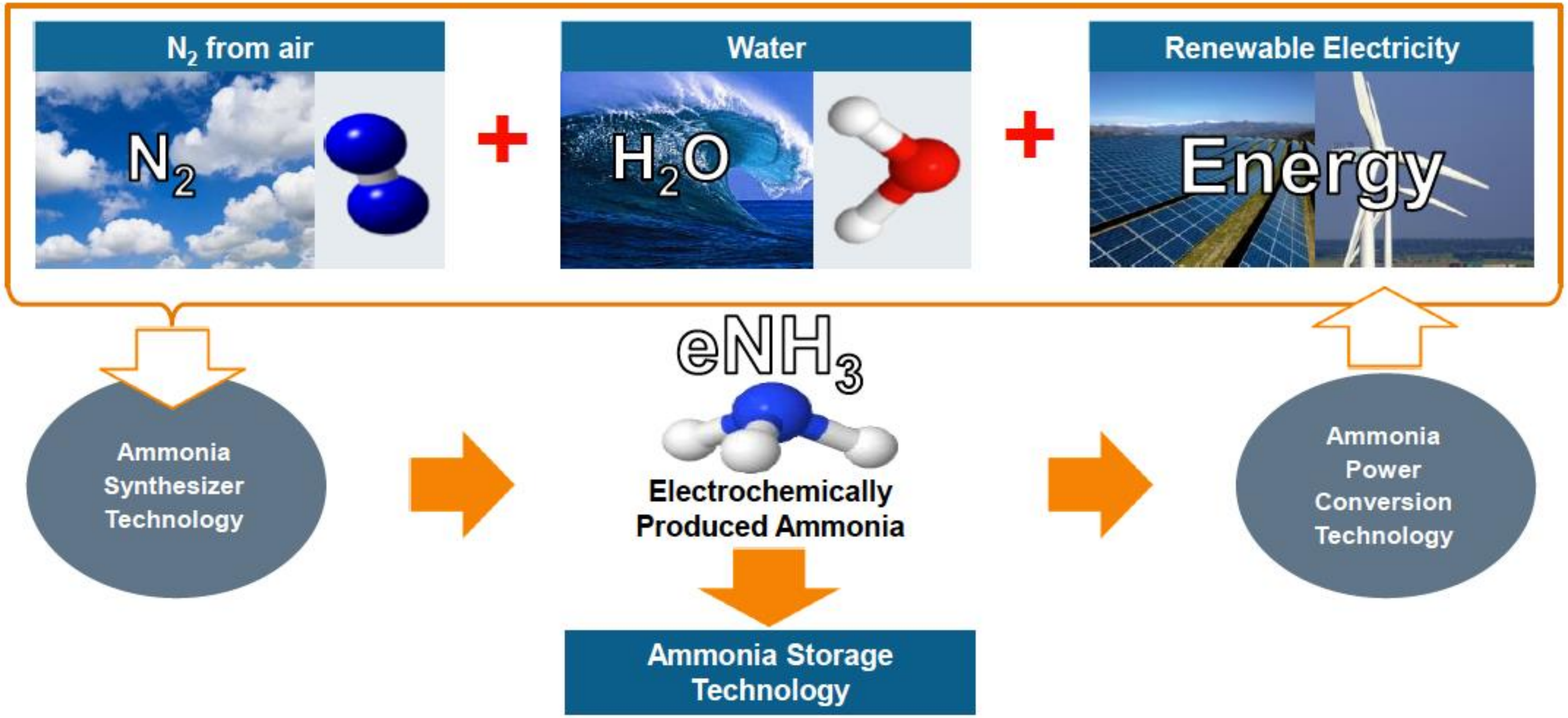
Technical and production aspects:

- 6 MW Electrolyzer (3 Stacks à 2 MW peak) delivered in 07/2015
- 1000 kg storage (33 MWh)
- 200 tons target annual output.

Project Scope
"Energiepark Mainz"

Partners: STADTWERKE MAINZ AG · THE LINDE GROUP · Hochschule RheinMain University of Applied Sciences Wiesbaden Rüsselsheim · SIEMENS · ENERGIESPEICHER Forschungsinitiative der Bundesregierung · Bundesministerium für Wirtschaft und Energie aufgrund eines Beschlusses des Deutschen Bundestages

Power to X



N_2 from air
N_2
Water
H_2O
Renewable Electricity
Energy
eNH_3
Electrochemically Produced Ammonia
Ammonia Synthesizer Technology
Ammonia Power Conversion Technology
Ammonia Storage Technology

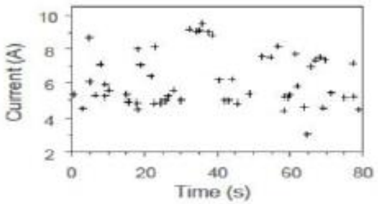
Innovation not only happens at the cell level
Battery Management and Operation in the Cloud

Physical models of the battery are used to inform data analytics working on large data sets through the connectivity provided by Mindsphere

Increasing Connectivity

Raw Data

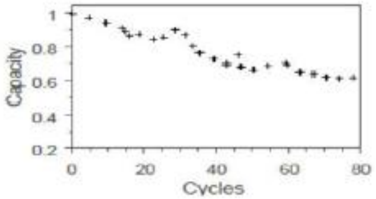
Raw waveforms (e.g. Current, voltage, temperature) from operated device



Battery sensors
(voltage, current, temperatures, EIS, RF)

Diagnostics

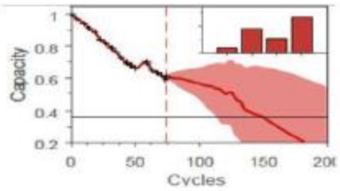
Physical models of the battery are used to determine SOH indicators



Physical
Battery Modelling
(Kalman Filter, reduced order electrochemical ......)

Prognostics

Data driven analytics are used to predict future health of the battery



Data Analytics
(Machine Learning, Neural Networks)

Optimal Operation

Multi-parameter application opimisation e.g. eBus fleet range optimisation

Optimal
Control Theory

- *Battery Management will become more critical as we start to utilise 2nd life EV batteries.*
- *EV communication systems will need to be more flexible and open to allow integration with (for example) the grid*

Figures courtesy of David Howey & Robert Richardson, University of Oxford

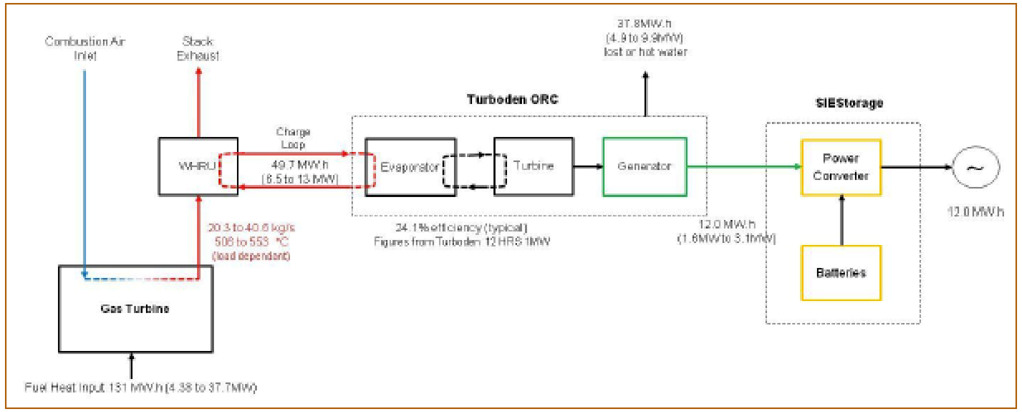
Integration of Storage & Buildings
Focus on SI, policy and Skills development

- *Within the H2020 STORY project, storage is integrated at different levels:*
  - *buildings (residential and commercial),*
  - *Micro-grids (industrial and residential)*
  - *MV distribution grids*
- Integration of storage in domestic building is still a market in development. Design of Intelligent appliances are not coordinated with storage design .
  - Battery management systems (BMS) are not communicating well
  - Limited experience in designing, building and managing the batteries
- Building level optimization becomes challenging when EV and building management systems are not integrated/coordinated
- Lack of clear regulation on the position of storage: is it generation or not?
- Lack of clearness on impact:
  - In Flanders you have to pay a fixed fee for the use of the grid in case you have PV
  - When installing batteries, a good battery management can support the grid. But there is not regulation on the assessment of the positive effect
- The combined integration of thermal and electrical storage in single buildings requires skilled people during the conceptual design. When it comes to the control …. It is nearly impossible.
  - There is a need for projects on optimized flexible control for the full management of on site generated heat and electricity with direct use, short term storage, static and dynamic storage and seasonal storage.

Waste Heat Recovery & Storage
Slow uptake from industry

Slow political process and political interference at all levels

- Organizational aspects: the lack of a multi-level governance
  - On the side of decision makers at local, regional and national authorities
  - On the side of the different stakeholders delivering, distributing and receiving the waste heat
- The cost-benefit aspect:
  - What do I get?
  - What are my responsibilities, including security of supply?
  - What are the consequences and to what extend does it influence my flexibility as a company?
- The strong position of utility companies wrt the use of district heating and cooling systems
- The cost and the size of thermal storage to balance supply and demand is significant. 1 euro per liter is acceptable.
- Integration remains the main cost aspect.



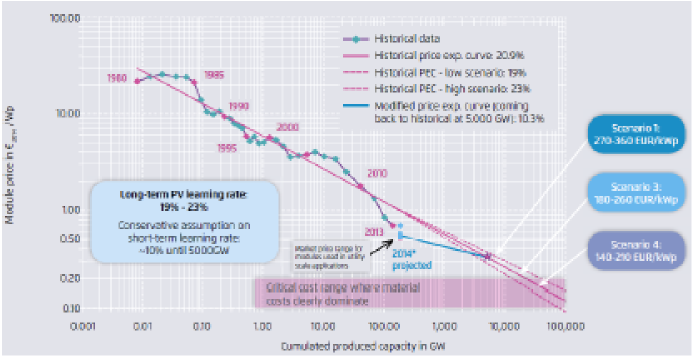
Context - Drivers for the future implementation and resulting Effects

Further decreasing costs of PV and wind generation lead to

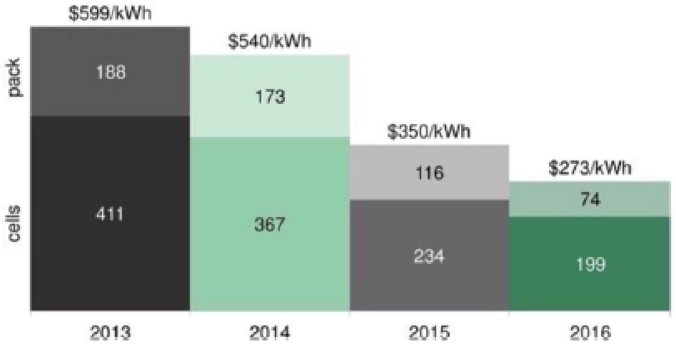
- increased global market growth and further integration measures
- improved economic boundary conditions for the implementation of PV Home Storage

Significant increase in production volume of electric vehicles lead to decreased battery costs which lead to

- better economic boundary conditions for stationary storage systems and new applications
- a stronger dominance of battery based storage systems



Source: Fraunhofer ISE



Research for System integration aspects (1/2)

“Active consumers” are defined as individuals or groups “who consume, store or sell electricity generated on their premises, including through aggregators, or participate in demand response or energy efficiency schemes”, but who do not do so commercially / professionally.

Standardised system integration approaches for all relevant stakeholders (market participants, system operators, customer & storage operators) including

- Standardized and robust interfaces and functions to allow for the provision of market services as well as measurement, billing and clearing
- Tools for local DSOs to assess and parametrize (e.g. grid functions) systems to allow for market participation of active customers with energy storage
- Robust Cyber Security and privacy approaches to ensure safe and reliable storage operation

Research for System Integration aspects (2/2)

“Local energy communities” are defined as organisations “effectively controlled by local shareholders or members, generally non-profit driven or generally value rather than profit-driven…engaged in local energy generation, distribution, aggregation storage, supply or energy efficiency services, including across borders”.

For the successful implementation with regards to storage technical aspect have to be clarified including

- Integration and interaction with the local DSO (Distribution system operators shall not be allowed to own, develop, manage or operate energy storage facilities; Transmission system operators shall not be allowed to own, manage or operate energy storage facilities)
- Control strategies and component interaction between single entities in the local energy community including relevant functions and interfaces

Research for Regulatory Aspects

Regulatory authorities shall perform at regular intervals or at least every five years a public consultation in order to re-assess the potential interest of market parties to invest, develop, operate or manage energy storage facilities.

Required for this are

- Key Performance Indicators and assessment methods for the implementation and usage of storage systems
- Clear technical specifications and standardized product datasheets as well as robust market numbers

Optimal Integration and operation of thermal storages

Non-residential thermal storages above 100 °C at TRL 4 – 7:

- Evaluation of cost-effective applications
- Optimal integration in terms of design, hydraulics and controls
- Combination with other technologies for heat supply

Enhancement of existing industrial components by integrating thermal storages at TRL 3 – 6:

- Phase change materials for temperature peak shaving and load shifting of e.g. electrical parts, heat exchangers, sensible storages etc.

Thermal Storages for Demand side management

Increase of process flexibility by dynamic operation of thermal storages at TRL 4 – 7:

- Power-to-heat with storage integrated electrical heat elements
- On-site untilisation of fluctuating renewable energy sources
- Optimization of discontinouse process operation
- Effective and robust dynamic control

Reduction of investment costs and development of business models

- Simple and easy to replicate design
- Use of cheap and abundant materials
- Considering contracting models for payback periods more than 3 years

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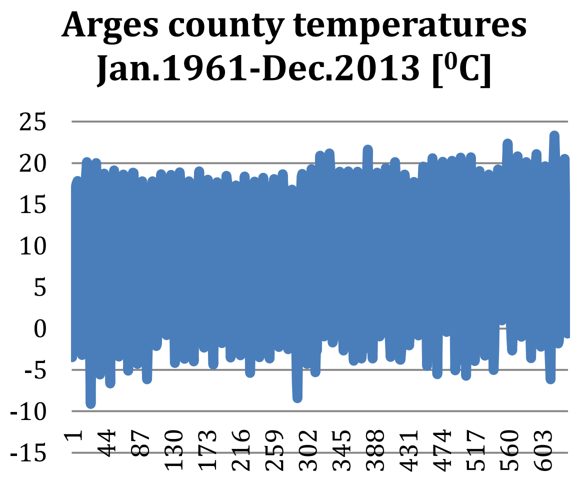
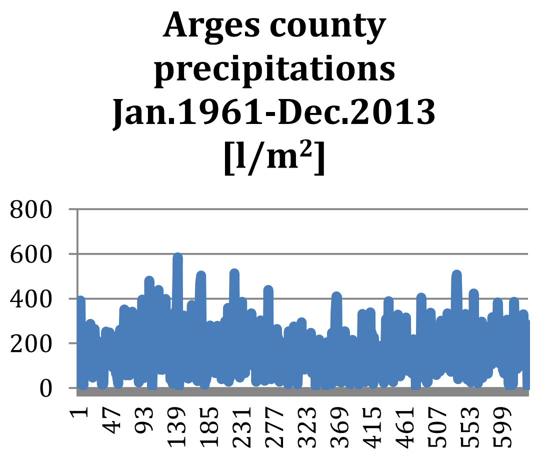
Big data evaluation of climate change risk events circular economy and smart cities

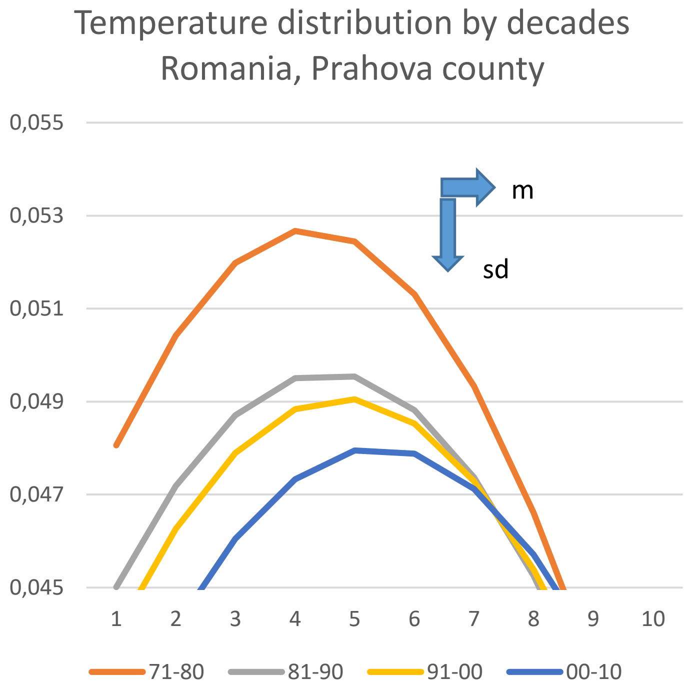
Big data analysis of climate parameters and risk maps – Romania example

The change of the climate is characterized by the increase in temperature and a larger standard deviation of the temperature distribution. Having the data of temperature for each of the 40 regions of Romania on a monthly basis in time, starting 1961, a two fold analysis was done: first, with the purpose to check the evolution of the average temperature and of the associated distributions standard deviation and second, to assess the risks stemming from the combined effects of temperature and precipitation in each region that result in flood and drought and snow and freeze risks.

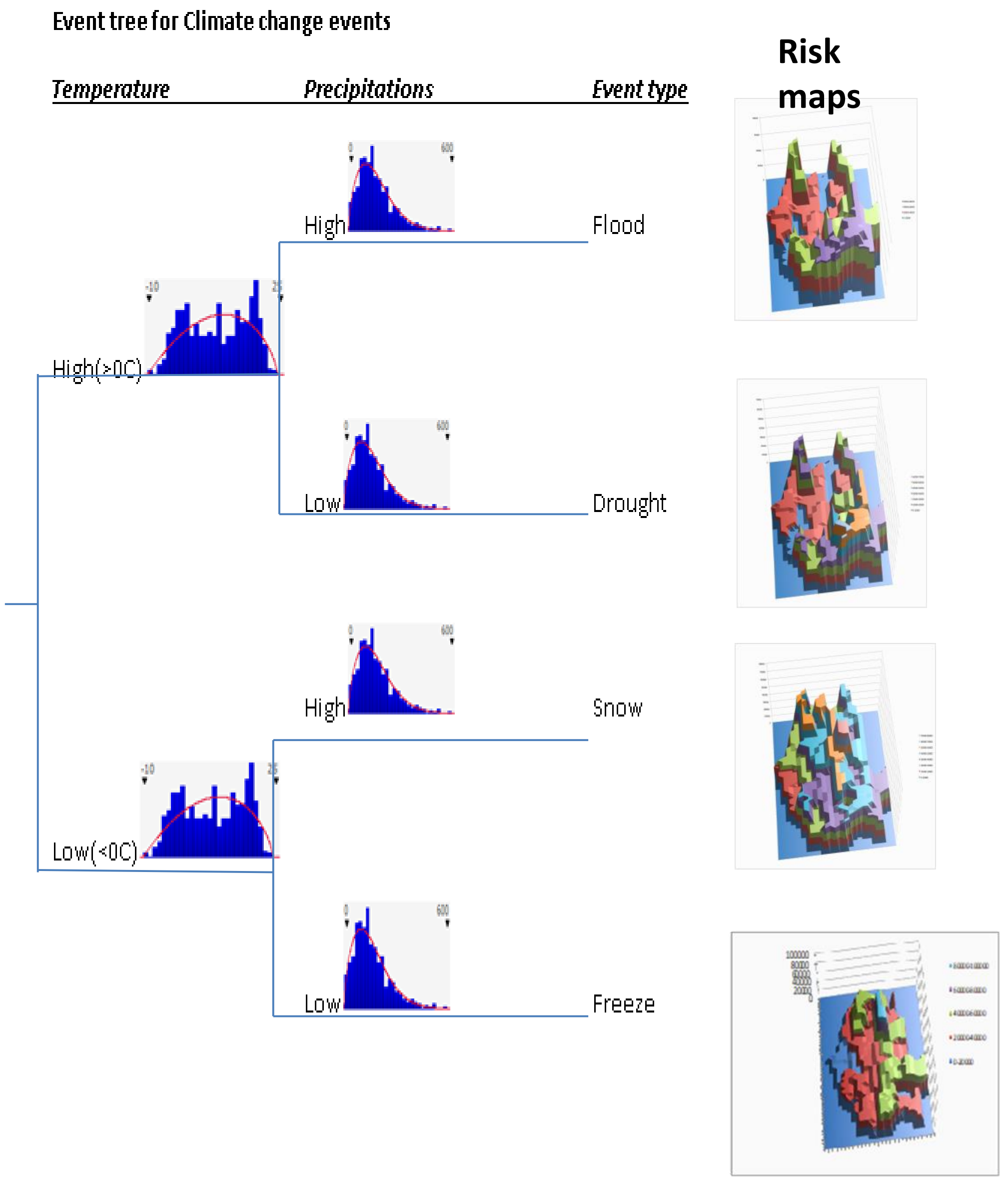
Big data analysis of climate parameters and risk maps – Romania example





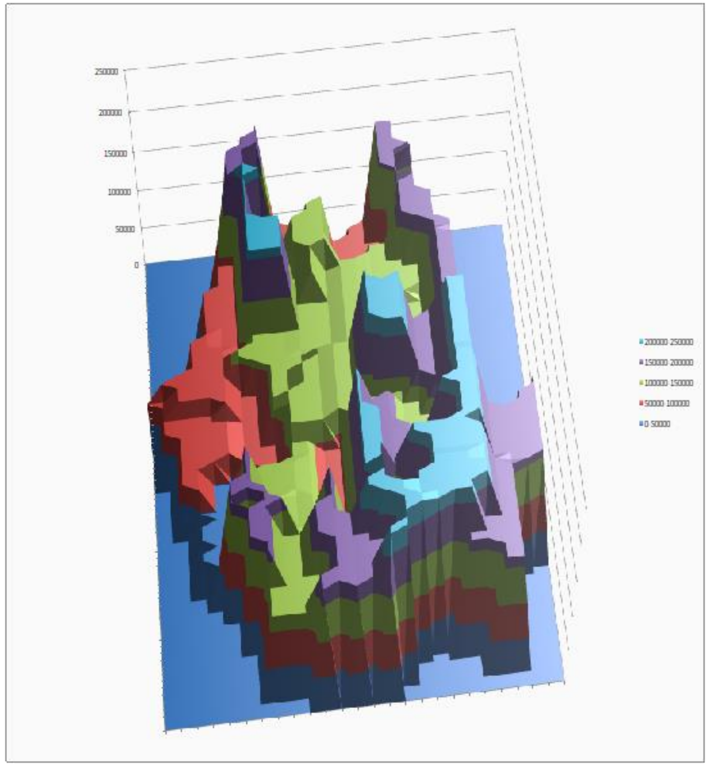


Big data analysis of climate parameters and risk maps – Romania example



Insurance policy against climate change

Total CC events risk map [thousands US$]

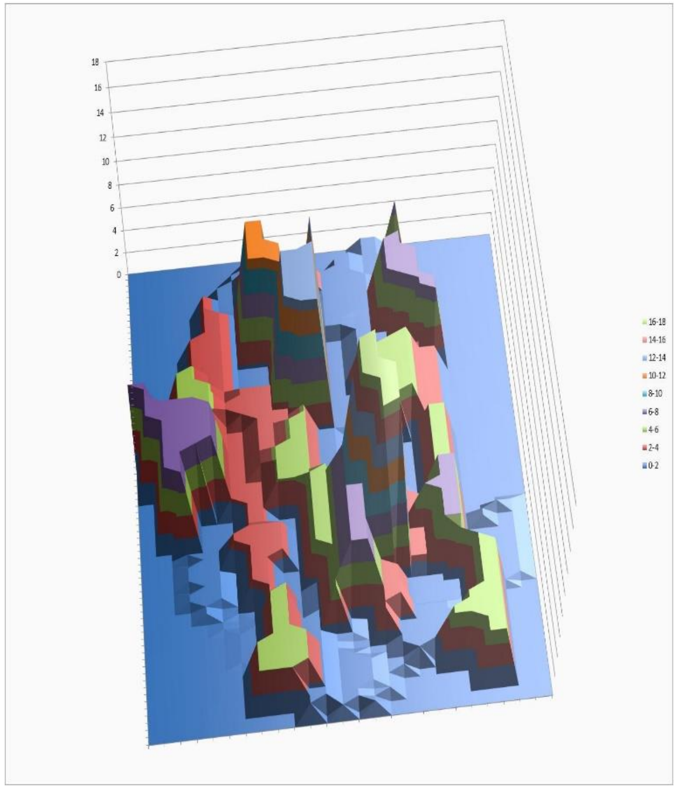


distribution of risk pemium per capita

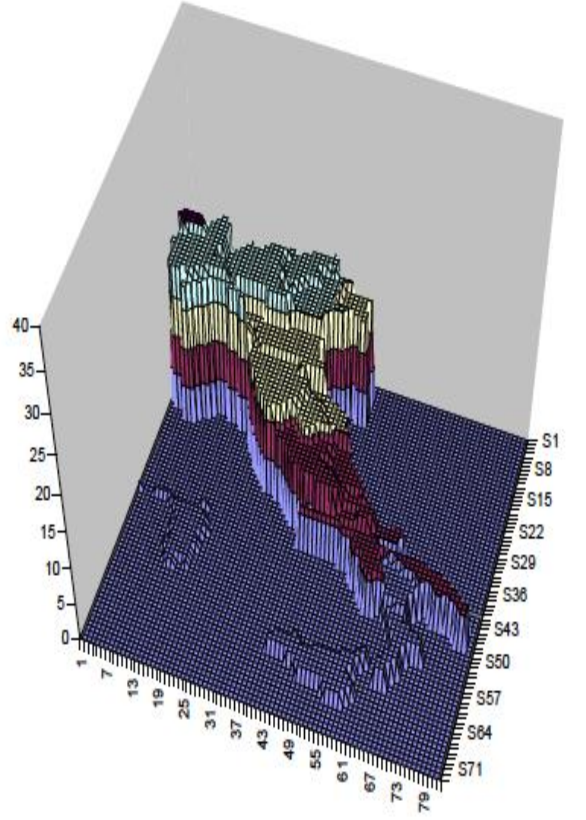
County	Premium Risk /cap US$	County	Premium Risk /cap US$
Bucuresti	0	Harghita	19.68
Alba	17.05	Hunedoara	8.44
Arad	11.81	Ialomita	43.59
Arges	8.28	Iasi	12.27
Bacau	8.33	Ilfov	6.68
Bihor	8.43	Maramures	8.31
Bistrita Nasaud	27.29	Mehedinti	32.56
Botosani	20.53	Mures	11.32
Braila	35.06	Neamt	11.59
Brasov	12.96	Olt	21.09
Buzau	16.20	Prahova	11.77
Calarasi	40.17	Salaj	51.13
Caras Severin	8.74	Satu Mare	31.13
Cluj	8.77	Sibiu	17.69
Constanta	13.86	Suceava	5.13
Covasna	59.81	Teleorman	23.70
Dambovita	22.91	Timis	6.71
Dolj	9.90	Tulcea	36.61
Galati	20.83	Valcea	15.41
Giurgiu	46.07	Vaslui	22.73
Gorj	16.76	Vrancea	25.50

Impact on gas grids – distributed risk

Romania gas grid CC and mechanical risk [probable deaths/1000 cap]



Natural gas risk in Italy [probable deaths / million inhabitants]



Measuring circular economy – complex indicators

Table 5.1 Macro level circular economy indicators (Geng et al., 2012)

Category	Indicators used
1. Resource output rate	Output of main mineral resource, output of energy.
2. Resource consumption rate	Energy consumption per unit of GDP, energy consumption per added industrial value, energy consumption per unit of product in key industrial sectors, water withdrawal per unit of GDP, water withdrawal per added industrial value, water consumption per unit product in key industrial sectors, coefficient of irrigation water utilisation.
3. Integrated resource utilisation rate	Recycling rate of industrial solid waste, industrial water reuse ratio, recycling rate of reclaimed municipal waste water, safe treatment rate of domestic solid wastes, recycling rate of iron scrap, recycling rate of nonferrous metal, recycling rate of waste paper, recycling rate of plastic, recycling rate of rubber.
4. Waste disposal and pollutant emissions	Total amount of industrial solid waste for final disposal, total amount of industrial wastewater discharge, total amount of sulphur dioxide emissions, total amount of COD discharge.

Measuring circular economy – complex indicators

Table 6.1 Broad classifications of current indicators potentially relevant to the circular economy

Indicator type	Examples	Availability of data	Relevance to the CE
Sustainable development	Social economic development, sustainable consumption and production, social inclusion, demographic changes, public health, climate change and energy, sustainable transport, natural resources, global partnership, good governance (Table A2)	Voluntary based reporting via EU Directorate-General for Energy (focused), European Sustainable Development Network (ESDN); corporate sustainability indicators (e.g. carbon disclosure)	Natural resources, sustainable consumption and production
Environmental	Agriculture, air pollution, biodiversity, climate change, energy, fisheries, land and soils, transport, waste, water	Regulatory based reporting via EEA cores indicators and country-specific statistics	Waste generated, packaging waste generation and recycling
Material flow	Domestic extraction, direct material consumption, domestic material input, physical trade balance, net additions to stock, domestic processed output, total material requirement, total domestic output	Eurostat, SERI	All
Societal behaviour	Sharing, municipal waste recycle, waste generated per capita (total and segregated), environmental/resource taxation	National and voluntary organisation statistics	All
Organisational behaviour	Material flow accounting in organisations, remanufacturing, use of recycled raw materials, eco-innovation, per capita statistics (e.g. reduction in waste generation per capita)	Private sector voluntary reporting via EU Forum for Manufacturing; ZVEI (German Electrical Industrial Association); VDMA (German Engineering Federation); etc.	All
Economy performance	Resource productivity, recycling industry, green jobs, waste generation/GDP, 'transformation of the economy'	Eurostat EU Resource Efficiency Scoreboard	All

Measuring circular economy – complex indicators

Box 1 An illustration of a potential composite indicator

One possible combination would be as follows:

- energy productivity (GDP/total primary energy supply) where larger values are associated with progress;
- GDP per capita (GDP/population): the present indicator for progress;
- the rate of resource recycling (recycle rate as a percentage): improved recycling would increase this indicator
- divide by the amount of carbon dioxide emissions, so reducing emissions would increase the indicator.

According to the formula

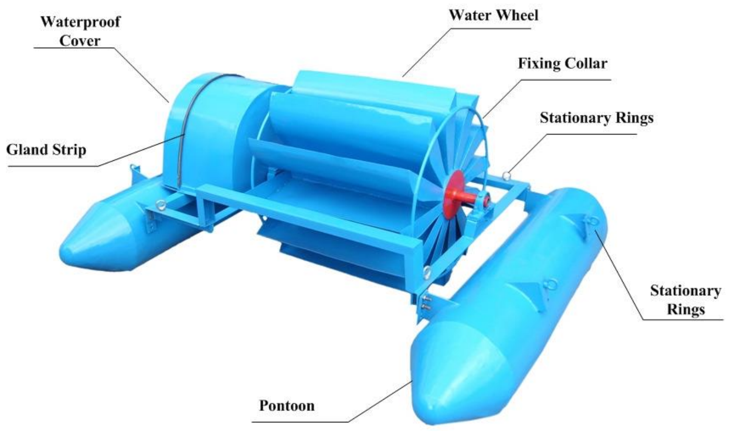
$$\frac{\text{GDP} \times \text{GDP} \times \text{recycle rate}}{\text{TPES} \times \text{population} \times CO_2 \text{ emission}}$$

Using data from IEA (2013) (except for the recycling rate), results in the following.

Country	Population	GDP (trillion US$)	TPES (toe per capita)*	CO_2 emissions (Mt CO_2)	Recycle rate (%)	Composite indicator value†
USA	314.3 M	14.232	6.8	5,074	37	2.2
Germany	81.9 M	2.851	3.8	755	45	19.01

*TPES, total primary energy supply; toe, tonnes of oil equivalent. †The composite indicator value is given as 10^8 US dollars per capita per tonne of oil equivalent of carbon dioxide.

Making energy smart cities – small city



Distributed energy solutions to use in an integrated way in a small city

Making energy smart cities – big city

Big city measures

Make energy strategy directorate at the level of the municipality or even the region

Identify the resources of energy and assess their use
Make evaluation of emissions and other risks
Determine available technologies (efficient, clean, secure, etc.)
Create unitary technology zones for heating
Increase buildings thermal insulation
Determine if and where to use distributed energy solutions
Monitor the electric grid (possibly with drones) for operational integrity
Monitor thermal grid for heat loss
Develop and implement technologies for passivation of buildings
Implement electric vehicles’ transport
Build battery charging network and distributed or grid charging devices
Consider building power plants to cover needed electrical energy for transportation.
Develop dedicated courses for the energy specialists
Devise innovative financial schemes and fiscal policy for the energy domain..

Conclusions

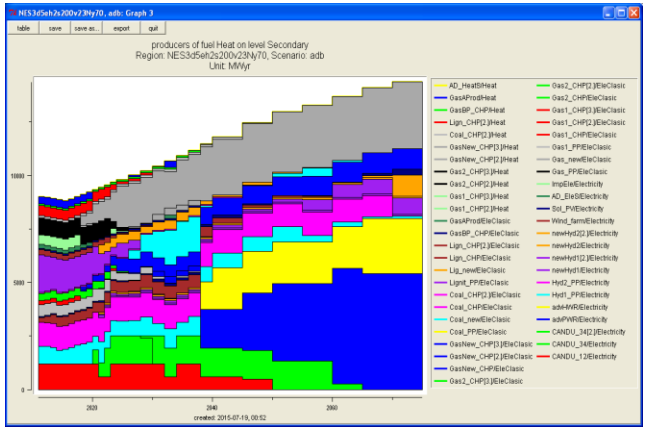
- Circular economy is the main vehicle to diminish environmental temperature increase.
- The exchange of resources with the environment must be reduced by generating new technologies that transform present waste liabilities into assets.
- Financing circular economy actions may be done based on a climate change insurance policy resulting from risk evaluation stemming from big data analysis.
- Measuring circular economy needs new complex indicators that shed new light on development values.
- Act to ‘smartize’ existing cities.

Modeling energy systems evolution MESSAGE

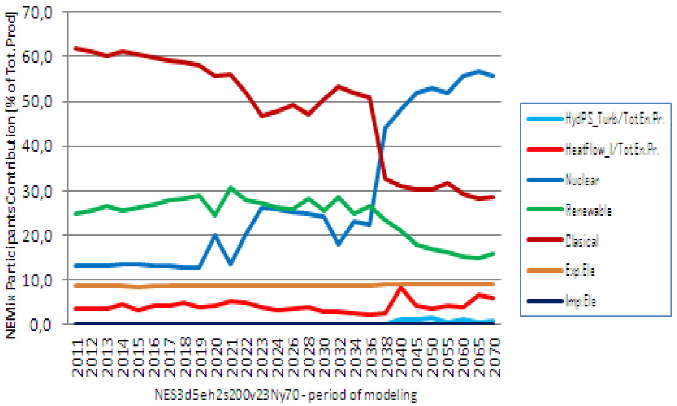
Technology penetration in the Romanian power system

Scenarios for technology penetration of ALFRED

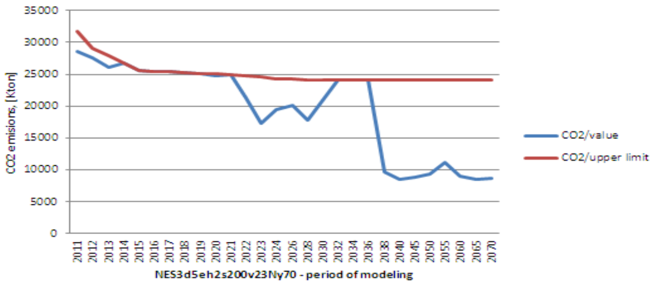
Total Energy Production



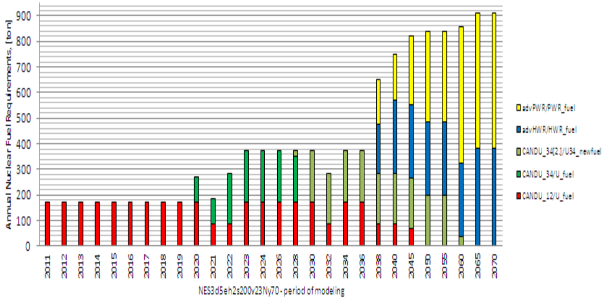
Distribution System Share



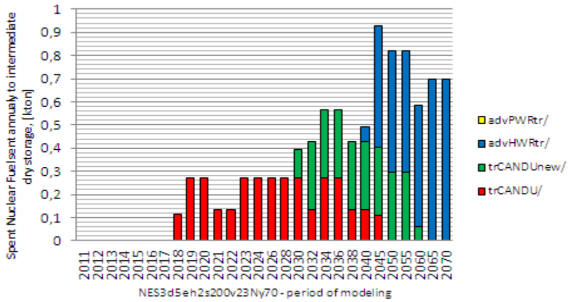
CO2 Emisions [kton]



Annual Nuclear Fuel Requirements, [ton]



Spent Nuclear Fuel Sent Annually to Intermediate Dry Storage, [kton]



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Thank you !

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