



# Sustainable Development of the Post-industrial Society. Nuclear Energy Inevitable Alternative

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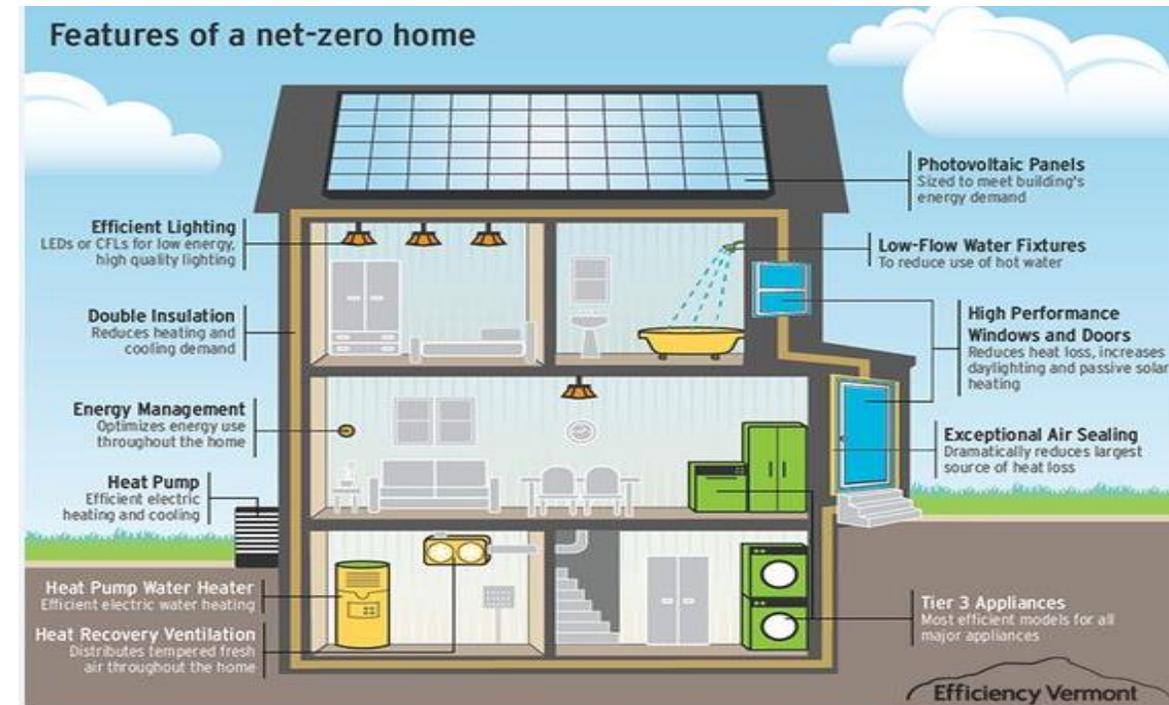
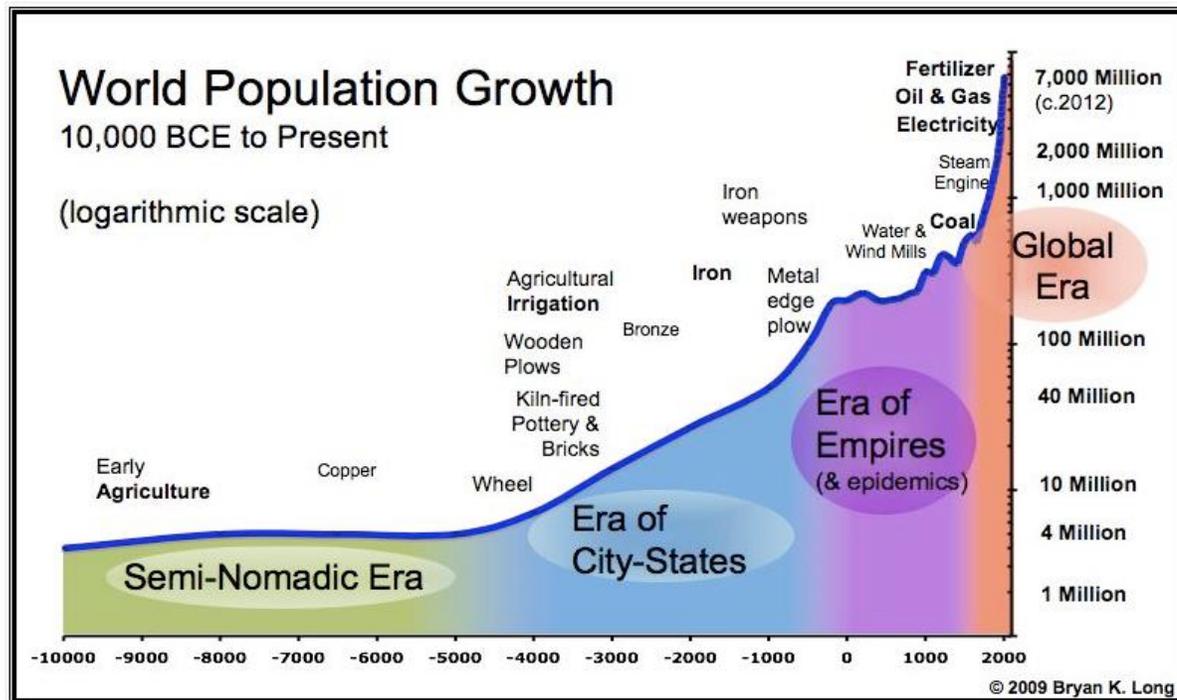
# From industrial Society to innovation and Industry 4.0

- The post-industrialized society is marked by an increased valuation of knowledge;
- In this case increase the “power” of knowledge together with the role of universities and research institutes;
- First step is intelligent innovation
- In the global landscape, the EU performs better than its competitors, such as China, Brazil, South Africa, Russia and India, while South Korea, Canada, Australia, the United States and Japan have a performance advantage over EU.
- Romania’s strengths are in Sales impacts, Digitalization and

Environmental sustainability based on European Innovation Scoreboard 2021

# Innovation goal

- Bill Gates: we need innovation to zero CO2 emissions!
- RES and Nuclear can really reduce C near 0.0!



# Nuclear and vRES

- **Very concentrated**
- **Reliable, base load**
- **Mature**
- **Some difficulties to load following**
- **Scalable**
- **30-60 y lifetime**
  
- **CO2 free**
- **Important costs for construction**



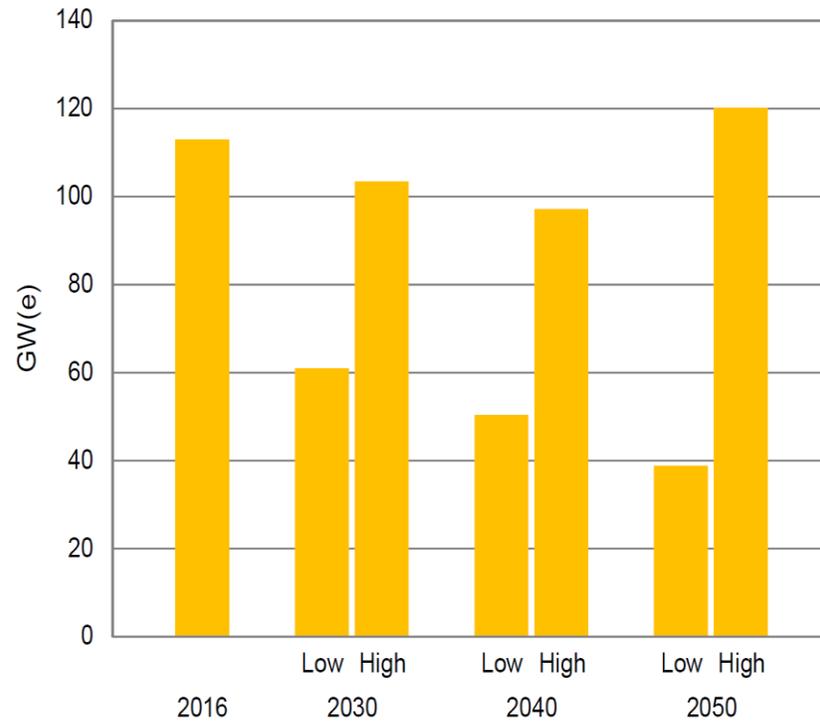
- **Diluted**
- **Intermittent (need storage and back-up)**
- **Young**
- **No load following**
- **Difficult to predict the production**
- **Lifetime?**
- **Fast development, RDI**
- **CO2 free**
- **Dominant cost: construction**
- **Public perception**



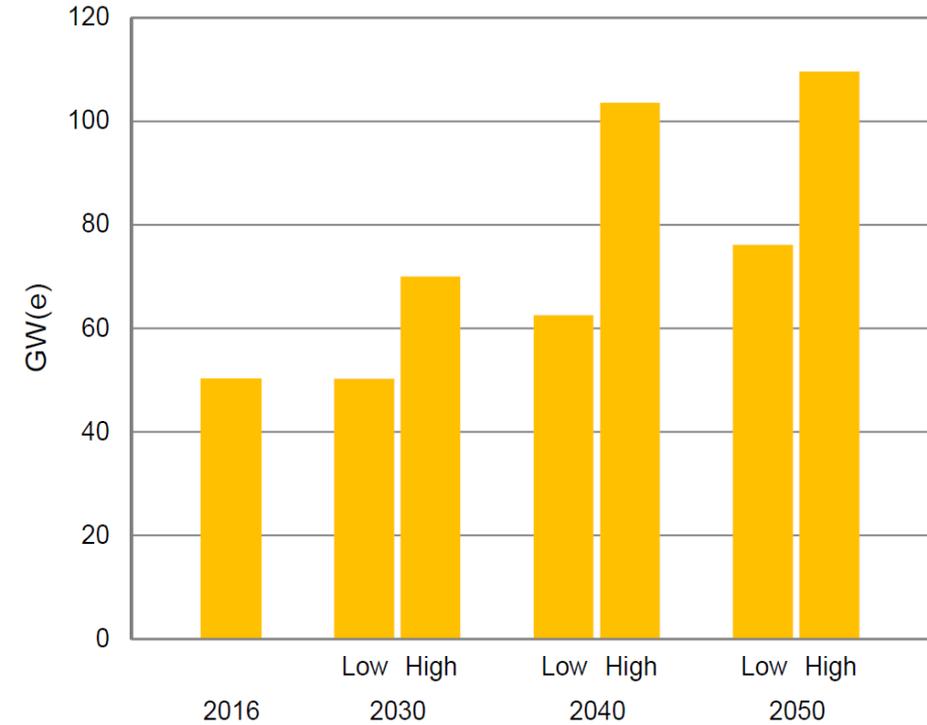
# Perspective of Nuclear in Europe

Source: "Energy, Electricity and Nuclear Power Estimates for the Period up to 2050", IAEA, 2017.

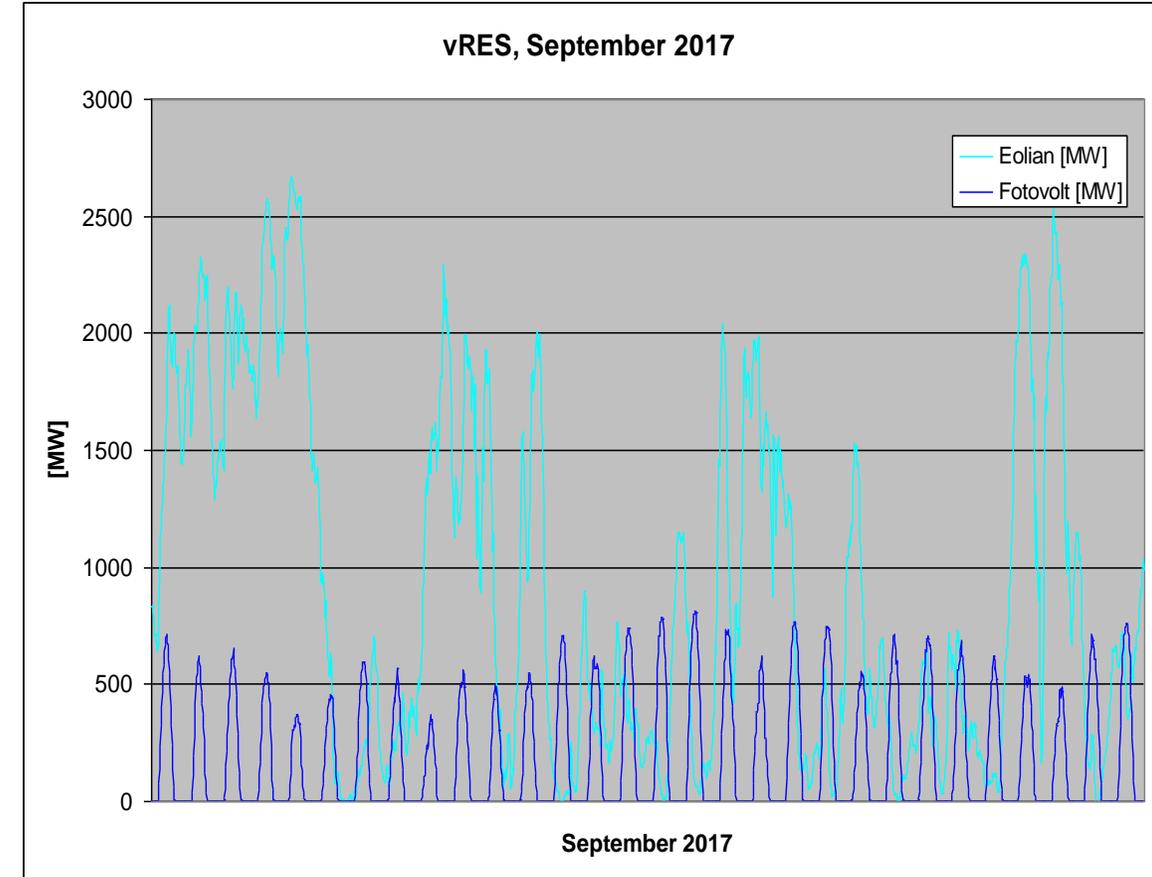
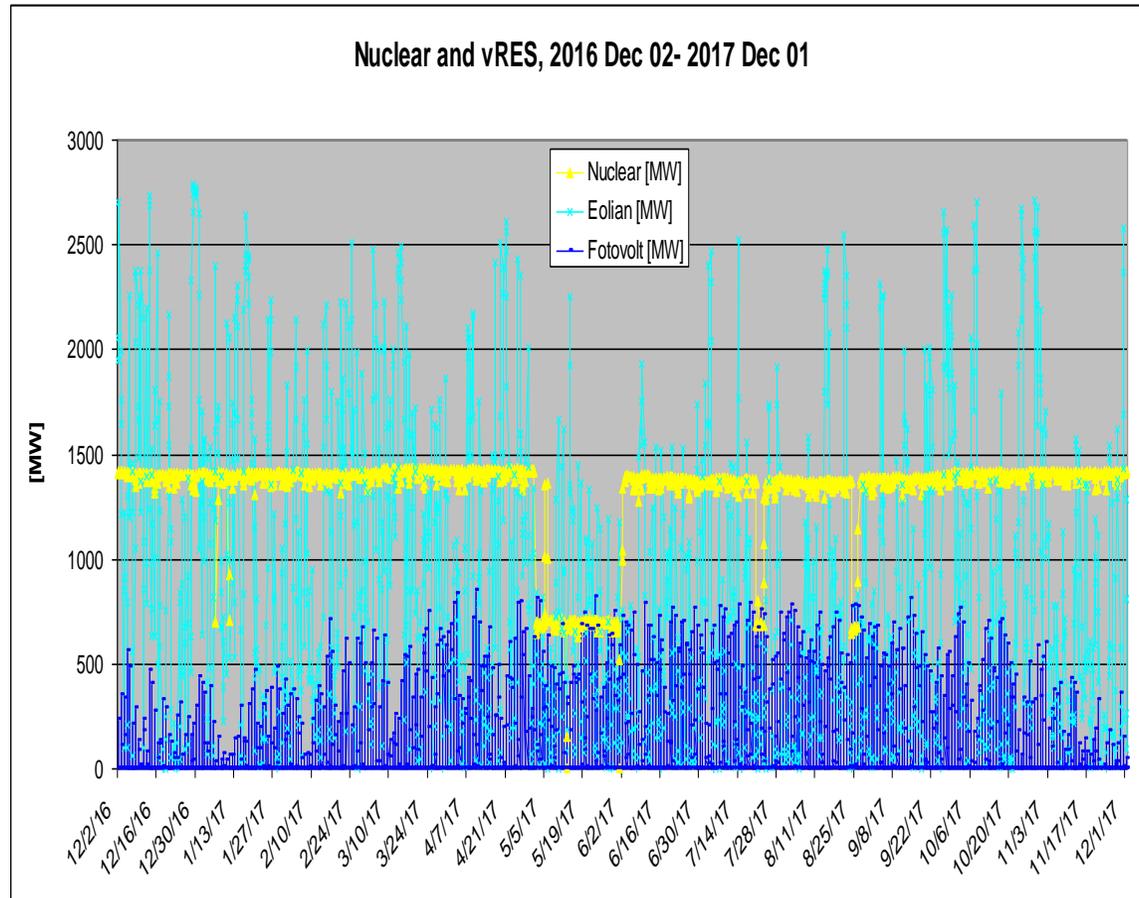
## Northern, Southern and Western Europe



## Central and Eastern Europe



# Romania, Nuclear and vRES, 2017



# Security of supply

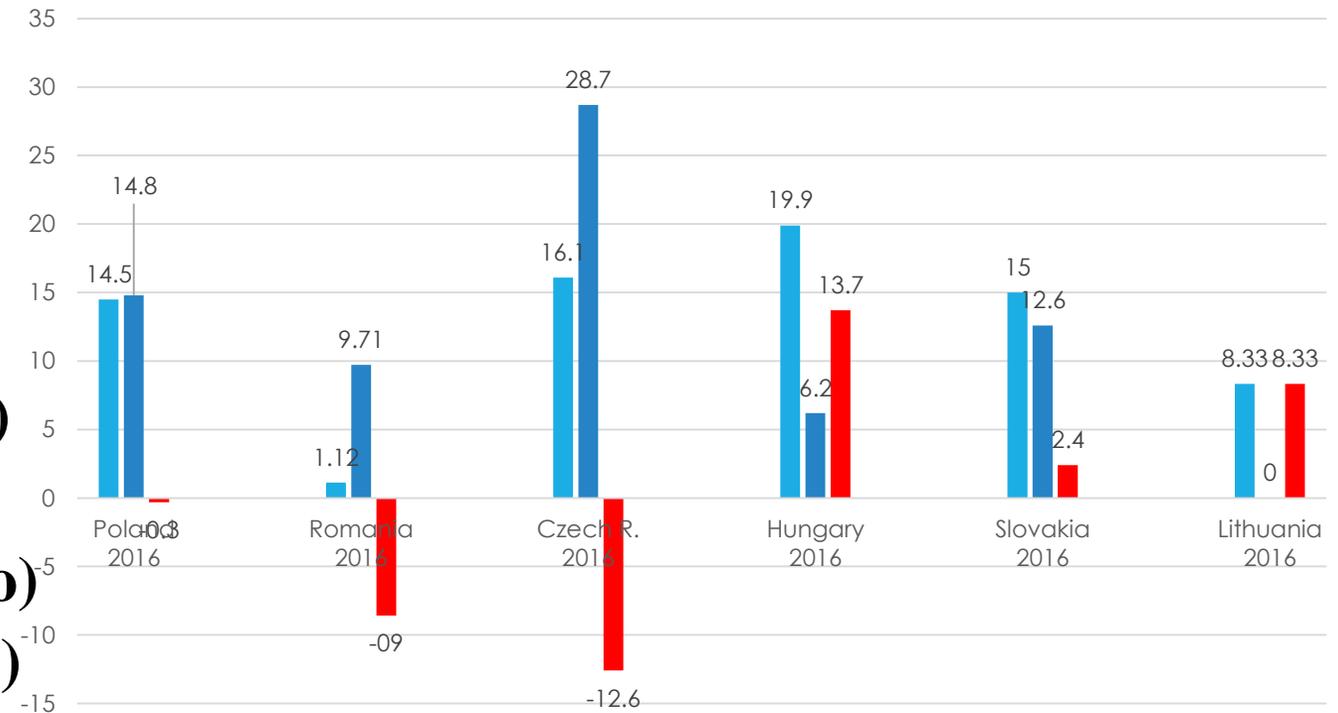
- **Electricity**

- **Net exporters – Cz, Ro**
- **Net importers: Hu, Lit**

- **Import of resources:**

- **Gas (Po, Hu, Cz, Sk, Lit)**
- **Oil (Po, Cz, Sk, Lit, Hu)**
- **Coal (Cz, Sk, Lit, Hu, Ro)**
- **Nuclear fuel (Cz, Sk, Hu)**

Import-Export of Electricity, 2016, [TWh]



# Back to innovation

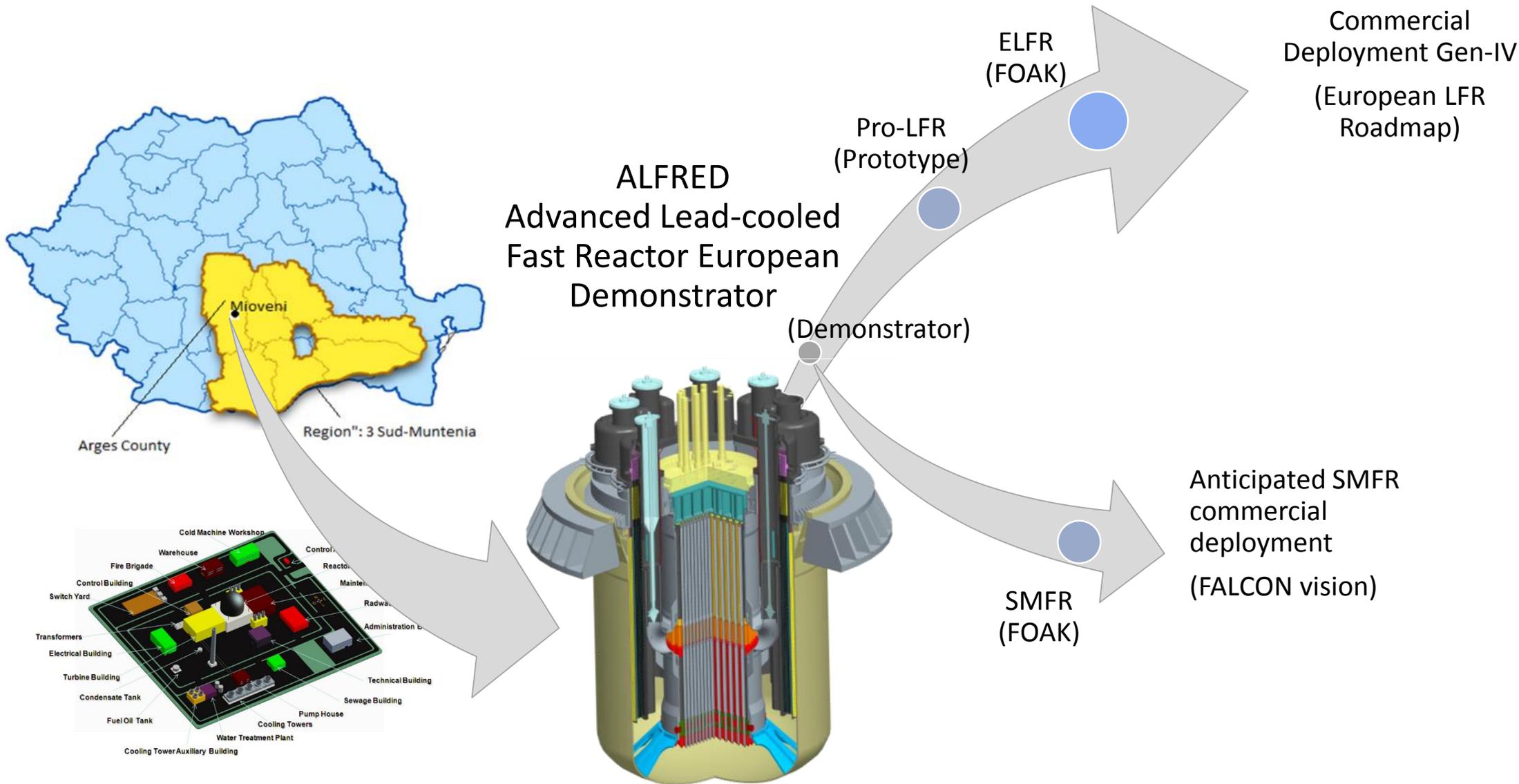
## ► Nuclear – weak points:

- Cohabitation with strong stimulated RES- Difficulties in load following, unable to operate as peaking capacity
- RWM
- Safety
- Siting and EPZ
- Limited resources (non-renewable)
- Proliferation

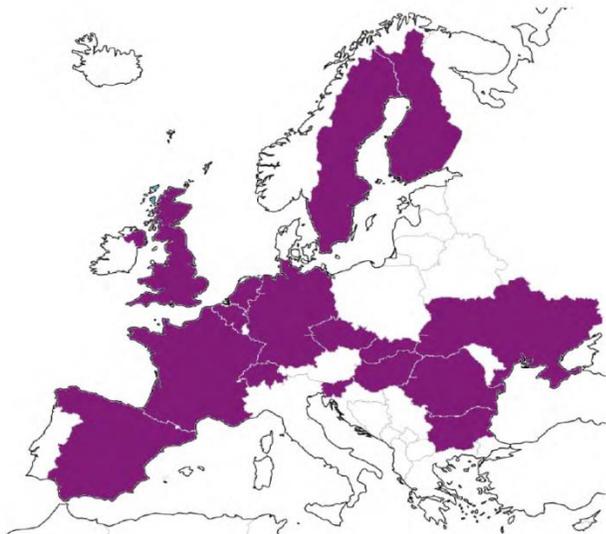
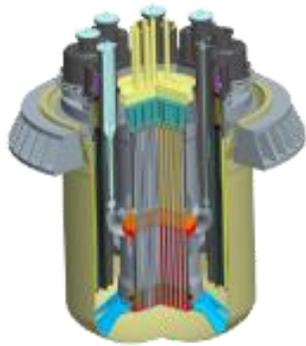
## ► Reserves:

- Innovation (G3, G4)
- New resources (e.g. Uranium from oceans)
- A new understanding at the societal level (climate changes, risks perception,... )
- Reduce the costs of electricity (use the lost heat)
- Reduce the capital costs (SMR, standardisation)

# ALFRED – LFR demonstrator and SMR features



# Benefits – European level



- Building excellent science to consolidate **European leadership** in nuclear technology
- **Sustainable development** of nuclear energy in Europe
- **Reduce the disparities** in development and RDI infrastructure of the regions
- **Boosting the collaboration** of European researchers and create bridges between NMS and developed countries
- **Stimulate industries and improving competitiveness**
  - **Innovative materials and components**
  - **Smart technologies**
  - **New procedures**
- **Pan-European Research Infrastructure**: create a **center of excellence** in the development of innovative LFR

# Benefits-National, Regional, and Local

- ▶ An opportunity for Romania to become the **focal point in the LFR technology** in Europe
  - consolidation of the nuclear sector: from users of the technology to developers
  - Greater sustainability of the use of natural resources: from natural U option to fast reactors
  - Geological disposal of SF: minimize the volume and radio-toxicity
  - Stimulation of the national research
  - Reduction of loss of high qualified human resources and young talents
  - Creation of new jobs, stimulation of development, strengthening the RDI poles
- ▶ Regional level (Sud Muntenia): ALFRED included in the Smart Specialization Strategy, as a key factor for:
  - economic growth,
  - improved innovation,
  - job creation,
  - strenghtening of RDI poles,
  - creating the career opportunities for young taltens,
  - visibility and reputation
- ▶ Local Council and ALFRED Local Group considerations
  - Growing of the local economy by a major investment
  - new high specialization jobs
  - Set up of a high performance RDI infrastructure
  - Keep young talents in the community
  - Stimulation of innovation and quality of research
  - Increase the visibility and reputation of local community



# ALFRED, an opportunity for Romania

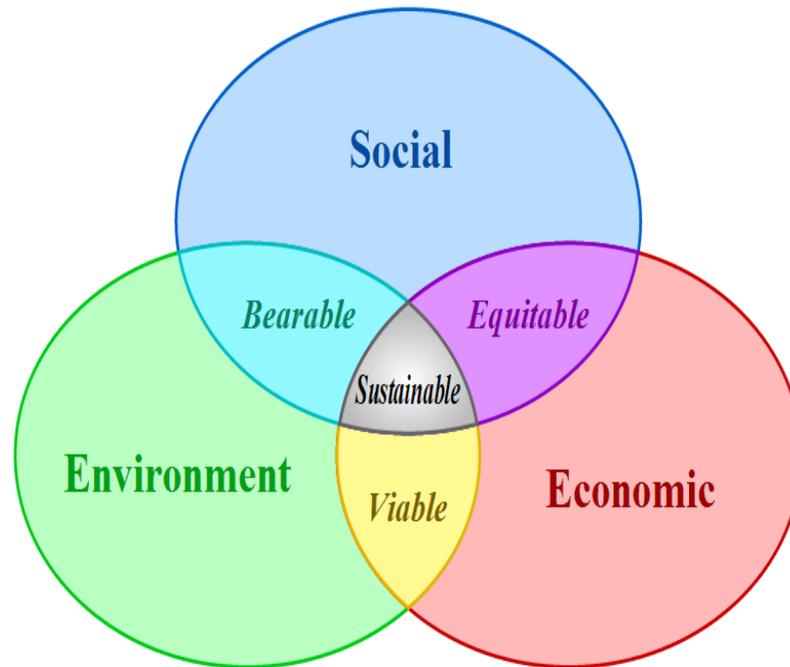
- 2011, Romanian Government – Memorandum on the interest to host ALFRED
- 2014, Memorandum “ALFRED construction in Romania”, 2014, approved by Government
- 2014, Mioveni nuclear platform as reference site
- 2015, ALFRED in Smart Specialization Strategy
- 2016, ALFRED in National RDI Strategy, and National Energy Strategy
- 2016: Letter of Support (ANCSI and scientific community)
- 2017, Support of the industry (ROMATOM)
- 2017, Research and Education Partnership for ALFRED, CESINA
- 2017, ALFRED in Roadmap of Major Research Infrastructure (CRIC) and in the National R&D Strategy
- 2018, [Romanian “Position paper” on ALFRED](#)
- the Government Programmes (for 2017-2020) and R&D Strategy mentions ALFRED
- 2021- Contract for Athena and CHEMLAB



# THE SUSTAINABILITY CONCEPT

Sustainability has been largely debated in various frameworks. In the nuclear field, the former meaning of this concept was mainly related to **fuel cycle aspects**, and particularly to what concerns the **uranium resources** duration and **spent fuel accumulation** with respect to a foreseen world reactor fleet.

IAEA has developed a comprehensive definition



**Figure 1**

**Venn Diagram Of Sustainable Development At The Confluence Of Its Three Constituent Aspects**

# SUSTAINABILITY AND GEN IV

The need for energy will increase in the future and, the natural resources will decrease, even if much more gradually than foreseen by catastrophist, hopefully compensated by the technological evolution in several fields;

Anyhow the sustainability concept is becoming more and more central.

**Are our Generation IV fast reactors  
Sustainable?**

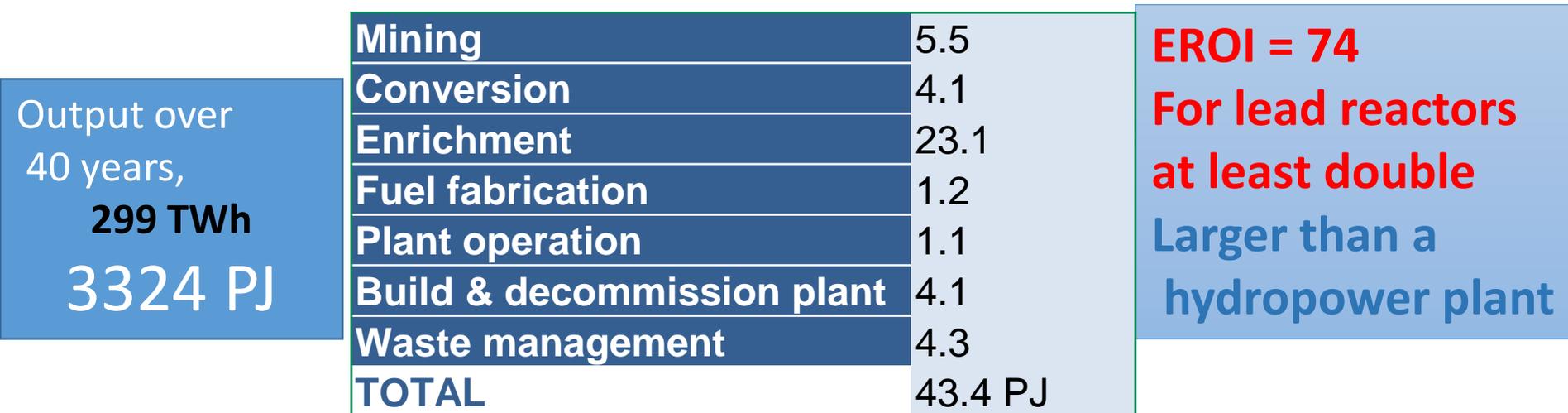
# ENVIRONMENTAL SUSTAINABILITY: EROI

The EROI (Energy Return On energy Investment) is a very effective environmental sustainability indicator, unexplainably underused.

The nuclear power plants have been usually assigned for net energy revenue ranging in between 10 and 50 meaning that on the overall plant cycle the net energy production is from 10 times to 50 times the energy needed for plant construction, operation and maintenance, full fuel cycle, decommissioning and waste maintenance.

Large differences come from the ore grade assumptions and different enrichment technologies; as an example, diffusion is highly energy expensive (EROI average around 15), while centrifugation is much efficient (EROI around 40).

Life cycle analysis for Vattenfall's Environmental Product Declaration for its 3090 MWe Forsmark power plant for 2002.lower-grade ores, or EROI is 74.



the input energy turns out to be 1.35% of output

# ECONOMICAL ESTIMATION

Assumed cost distribution for ELFR based on ELSY documentation

The nuclear economic sustainability has to be fairly evaluated in comparison with other type of sources showing comparable characteristics, i.e. dispatchable and CO<sub>2</sub> free; also for these systems, such as hydroelectricity, geothermic, fossil fuel with CSS and biomass, economic estimations are affected by many possible uncertainties, due, for example, to:

- Forecasts on fuel cost;
- Carbon Sequestration and Storage is still undefined in terms of technology to be adopted, costs and environmental impact;
- Forecast on load factor; the strong introduction of intermittent sources has driven the electrical mix toward the use of fast reacting systems - i.e. with good ability to change rapidly their power output - and has relegated some traditional sources to a minor role.

<b>Cost item</b>	<b>Optimistic</b>	<b>Nominal</b>	<b>Pessimistic</b>
R&D	-	-	-
Engineering, licensing & construction	3600 €/kWe	4100 €/kWe	4900 €/kWe
Engineering, licensing & construction (incl. 1 <sup>st</sup> core, D&D, contingencies)	4100 €/kWe	5200 €/kWe	6300 €/kWe
Operation & maintenance	81 €/kWe/a	110 €/kWe/a	143 €/kWe/a
Fuel cycle	4 €/MWh	8 €/MWh	19 €/MWh
Energy generation	22.5 €/MWh	37.5 €/MWh	69 €/MWh

# ECONOMIC SUSTAINABILITY

Levelised Costs For Electricity Production And Their Uncertainty Intervals, Plants Commissioning In **2025-35**. Nuclear Is the most cheap and the most mature technology. Technology Specific Hurdle Rates Are Used. Source: Elaboration On The Basis Of Data From Department Of Energy&Climate Change (DECC).

Technology type	projects commissioning in <b>2025</b> £/MWh		projects commissioning in <b>2030</b> £/MWh	
<b>Nuclear</b> FOAK/NOAK	<b>L M H</b>	<b>75-86-101</b>	<b>L M H</b>	<b>67 77 89</b>
<b>CCGT</b> with post-combustion CCS- FOAK	L M H	94 <b>105</b> 143	L M H	93 104 118
<b>CCGT</b> with pre-combustion CCS- FOAK	L M H	109 <b>124</b> 143	L M H	107 123 143
<b>COAL</b> ASC with ammonia, FOAK	L M H	120 <b>141</b> 170	L M H	116 137 165
<b>COAL</b> IGCC with retro CCS, FOAK	L M H	102 <b>120</b> 144	L M H	101 119 142
<b>BIOMASS</b> with CCS	L M H	174 <b>188</b> 239	L M H	174 188 239
<b>HYDROPOWER</b> 100kW- 1000kW	L M H	87 <b>154</b> 301	L M H	87 154 301

# Alfred framework

- ALFRED is a lead cooled reactor, of 120 MWe power, that will be connected to the grid to make a first step in the deployment of Lead cooled Fast Reactor (LFR) technology. The size of the reactor also fits the needs of a *Small Modular Reactor* (SMR), so that ALFRED on one side represents the LFR technology demonstrator, and, on the other one, the FOAK for a lead cooled SMR.
- Before building the demonstrator, substantial design and experimental activities (as well as supporting activities for licensing) are deemed necessary. The plan shall include at least two different phases:
  - **First step (2019-2025):** ALFRED exp. infrastructures, experiments and design
  - **Second step (2025-35):** ALFRED construction

# FALCON



In March 2011 the Romanian Minister of Energy wrote a letter to LEADER Project coordinator proposing to host ALFRED in Romania.

Ansaldo response to the Romanian Minister welcome the Romanian proposal and inform of the transmission of the letter of interest to ESNII members.

In June 2013 the sub-secretary of the Italian Minister for Economic Development wrote to commissioner Oettinger to highlight the importance of Alfred in the European context and the intention to use synergies between RTD and infrastructural funds for ALFRED Project.

Response from Commissioner Oettinger received in August 2013 welcome the Italian/Romanian proposal and highlights the importance and the usefulness of the synergies to pool resources and reach the critical mass for project deployment.

The FALCON consortium has been set-up on December 18<sup>th</sup> 2013 by: Ansaldo Nucleare, ENEA and ICN. Construction Site is Mioveni, and EU organizations are invited to join FALCON on a technical agreement (MoA).

# FALCON the main challenges



To be able to reach the phase of ALFRED construction we will have to face several challenges:

- Based on *Partnership Agreement-România-2014RO16M8PA001.1.2 art.174: "As regard the development of low-carbon energy technologies the objectives of SET Plan will be taken in due account"* is necessary to start the diligences at EU level to develop the financial schemes for ALFRED see ([http://www.fondurie.ro/res/filepicker\\_users/cd25a597fd-62/2014-2020/acord-parteneriat/Partnership\\_Agreement\\_2014RO16M8PA001\\_1\\_2\\_ro.pdf](http://www.fondurie.ro/res/filepicker_users/cd25a597fd-62/2014-2020/acord-parteneriat/Partnership_Agreement_2014RO16M8PA001_1_2_ro.pdf))
- Declare South-Muntenia nuclear smart specialization  
Such step are pre-requisite to be able to get cohesion funds !!
- Develop a new sound configuration of ALFRED
- Be able to erect facilities to support lead technology
- Show the safety features and obtain licensing

It is fundamental to have a transparent and efficient management of all activities. Activities in Romania and outside should be concentrated on one goal:

**the ALFRED development and construction**

# CONCLUSIONS

- the lead fast reactor sustainability discussion has been started.  
Assumed cost distribution for ELFR based on ELSY documentation
- The new conceptual design approach gives to this system inherent safety features that reduce the plant risk on the basis of the application of innovative physical concepts.
- A strong reduction of nuclear wastes and of their radio toxicity confers to nuclear energy a new high sustainability level.
- As a matter of fact, the fuel cycle specific improvements based on the adiabatic reactor concept optimized through a “by design” approach have a strong effect on the environmental impact posing the bases for a reconsideration of the public resiliencies.
- The EROI foreseen for IV generation systems is at the top value with respect to the other CO<sub>2</sub> free, or strongly reduced, energy sources.
- Nuclear power plants are already competitive with other sources, while cost extrapolation far away in time is quite difficult. The ELFR cost premium, with respect to generation III+, passive safety reactor, has been studied in details in the framework of the LEADER project and assessed to be of the order of 10%.
- *The Falcon consortium is rapidly progressing toward the final Alfred project definition*