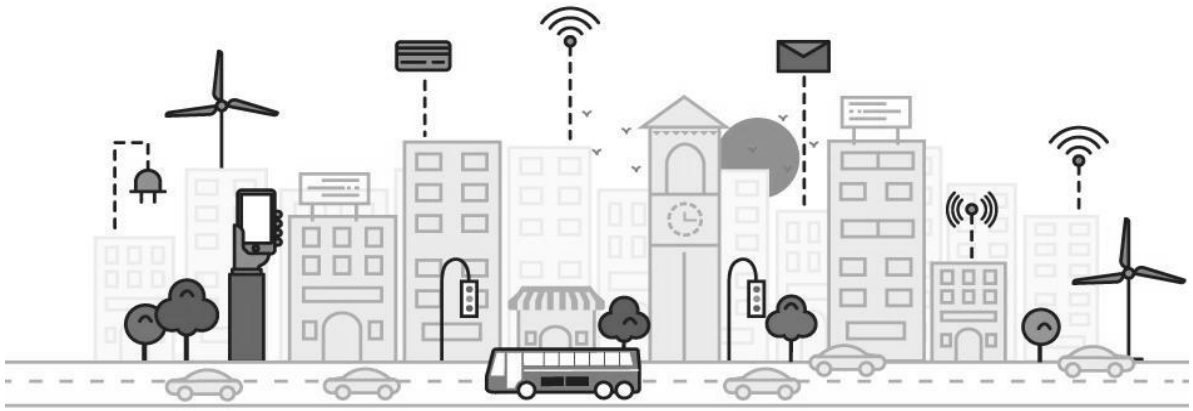


Smart Networks Smart Islands

Nikos Chatziargyriou
Chairman and CEO

HEDNO THE GREEK DSO

Within the **10 largest** Electricity Distribution Corporations in EU (based on the number of customers and the total network length)

Hellenic Electricity Distribution Network Operator S.A.

HEDNO (Hellenic Electricity Distribution Network Operator S.A.) is the organizationally and functionally independent Company in Greece, which distribute electricity to **7,4 million customers** across the country, through Medium and Low Voltage Networks with a total length of **Distribution Lines of 236.000 km**.
We employ about **6.500 people**

OUR MISSION

IS TO ENSURE

- the proper operation, maintenance and development of the Distribution Network all over the country
- **the proper operation and management of the Non-Interconnected Islands (NII's) Electrical Systems**
- the access of Producers and Suppliers to the NII's Electrical Systems and the proper operation of the NII's Market in terms of transparency and impartiality.

HEDNO's VISION AND STRATEGY

Vision

Our vision is to become the top Network Operator in South Europe achieving the optimal combination of **quality** and **low-cost** services, having as our first concern the **environmental protection**.

Investment Plan

Our investment plan is of a total average annual budget of **€250 million** for reinforcing and modernizing the Distribution Network including the implementation of 12 fundamental strategic projects.

Strategy

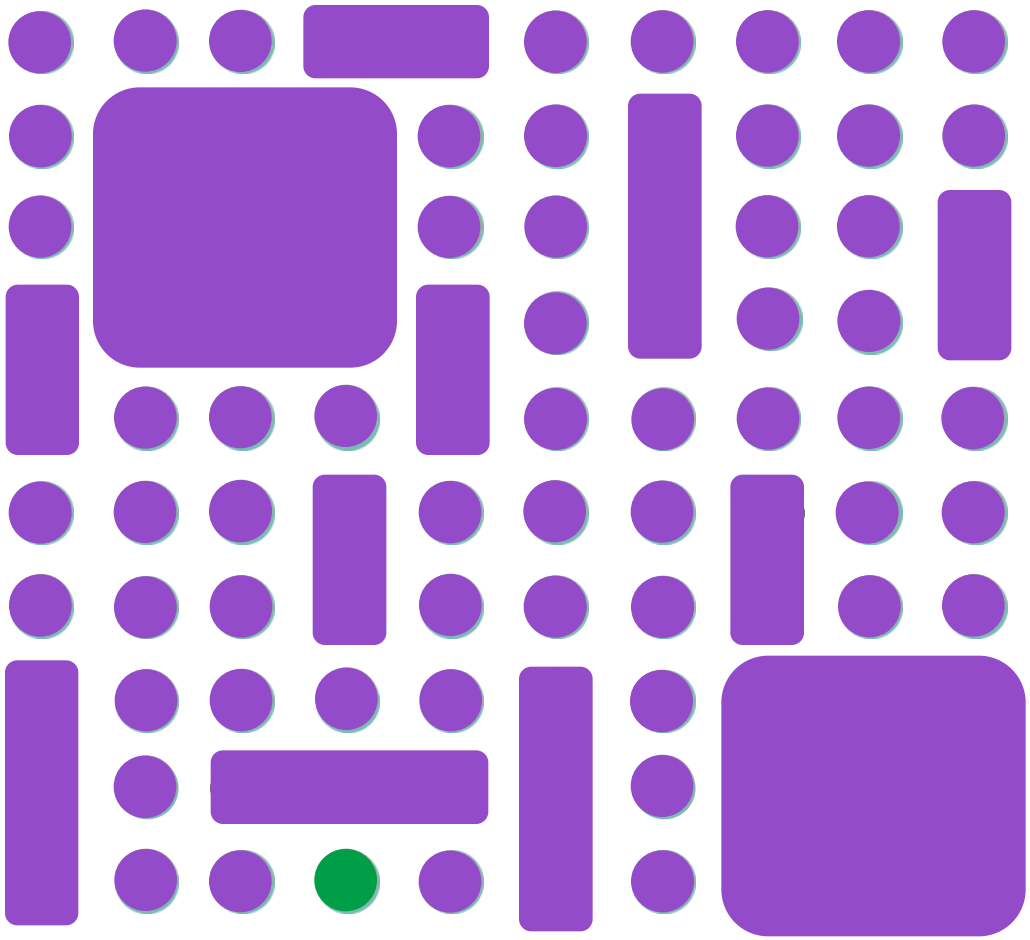
Our strategy refers to the **integration of new technologies** ("Smart Grids", Remote Metering, Remote Services, Automations etc)

Goal

Our goal is to modernize the Distribution Network and transform it into a "**Smart System**" that will continually optimize the management of the connected consumers and producers, covering their emerging needs by an optimal techno-economical way.

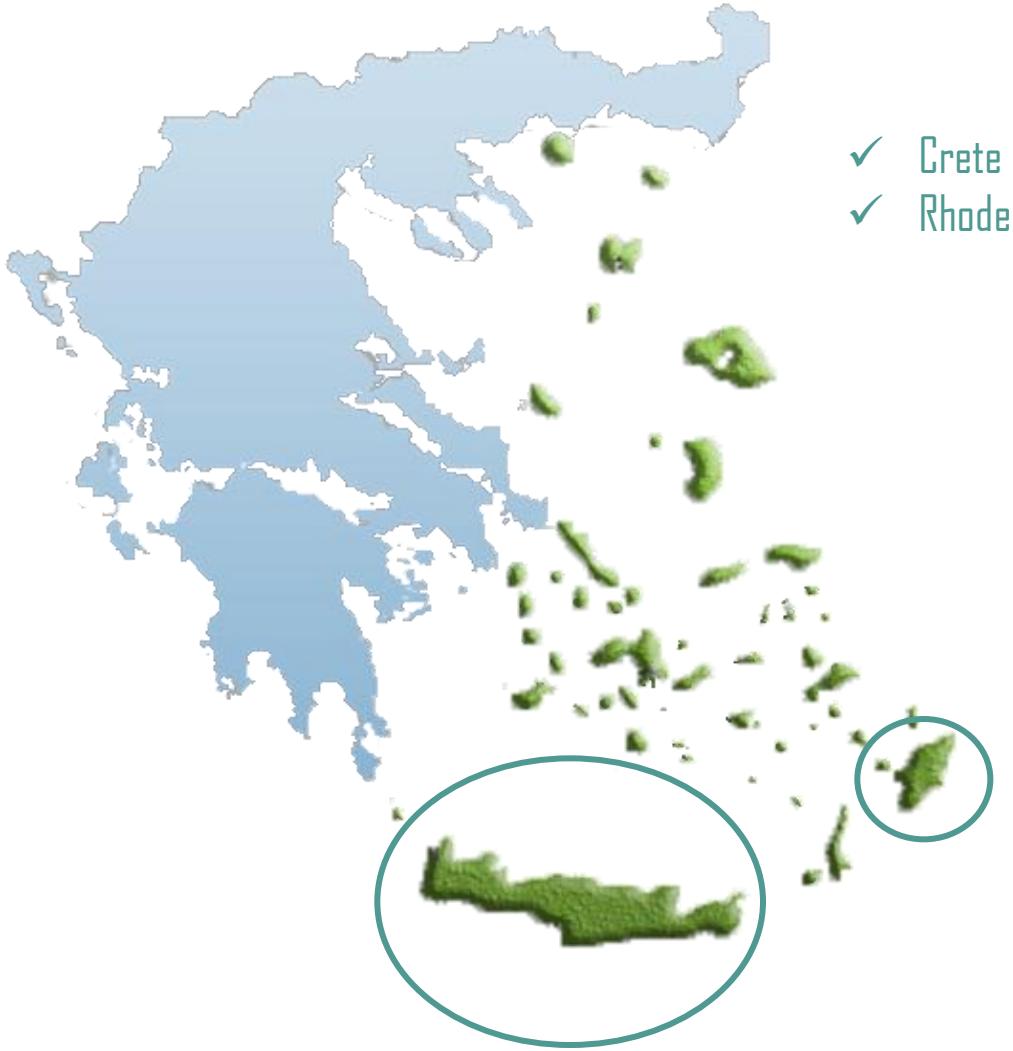
NII Structure

- 60 Islands
- 32 Electrical Systems (ES)
  - 11 ES consisting of 39 interconnected islands
  - 21 ES consisting of autonomus islands
- 31 Isolated Microgrids
- 1 Small Isolated System (Crete)



NII Structure

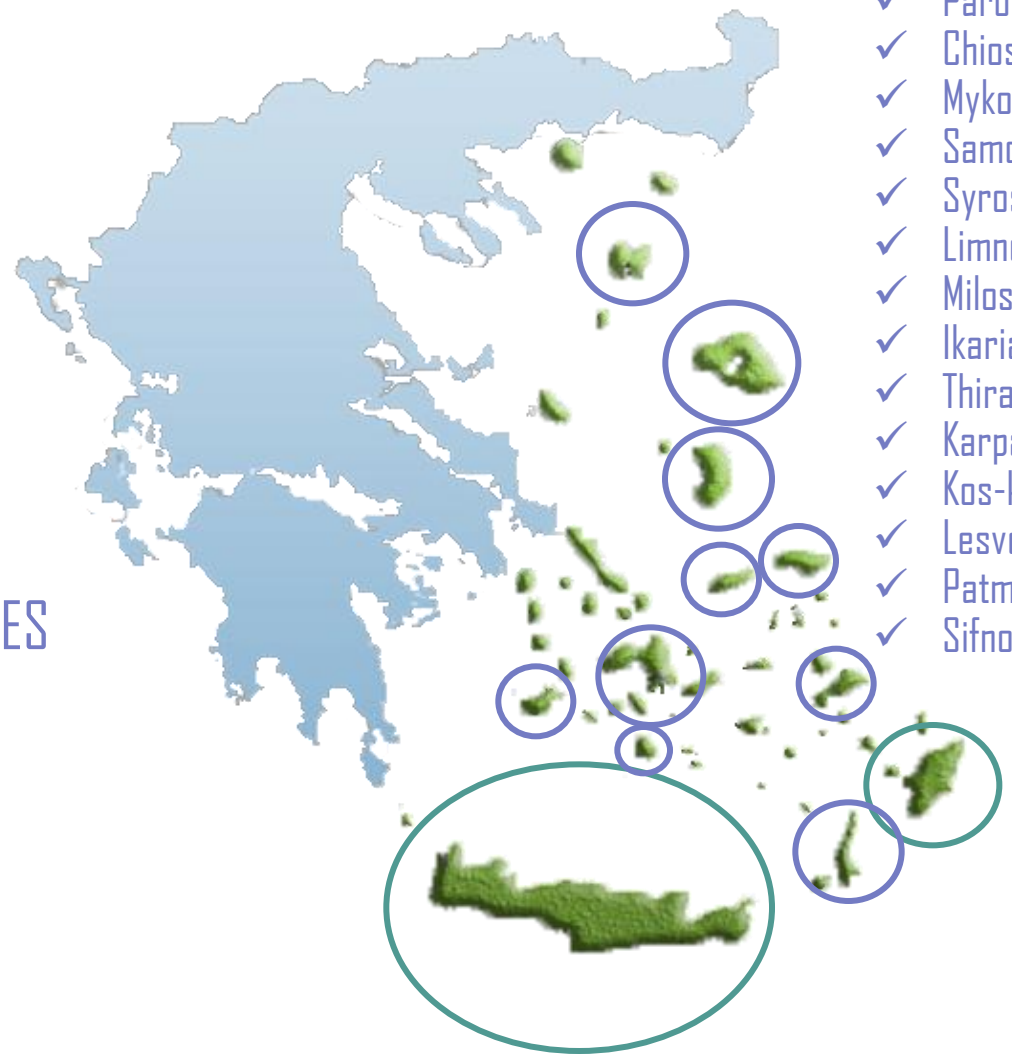
- 32 Electrical Systems (ES)
- Categorized by Average Peak Demand (last 5 years)
  - Large (>100MW) : 2 ES



- ✓ Crete
- ✓ Rhodes

NII Structure

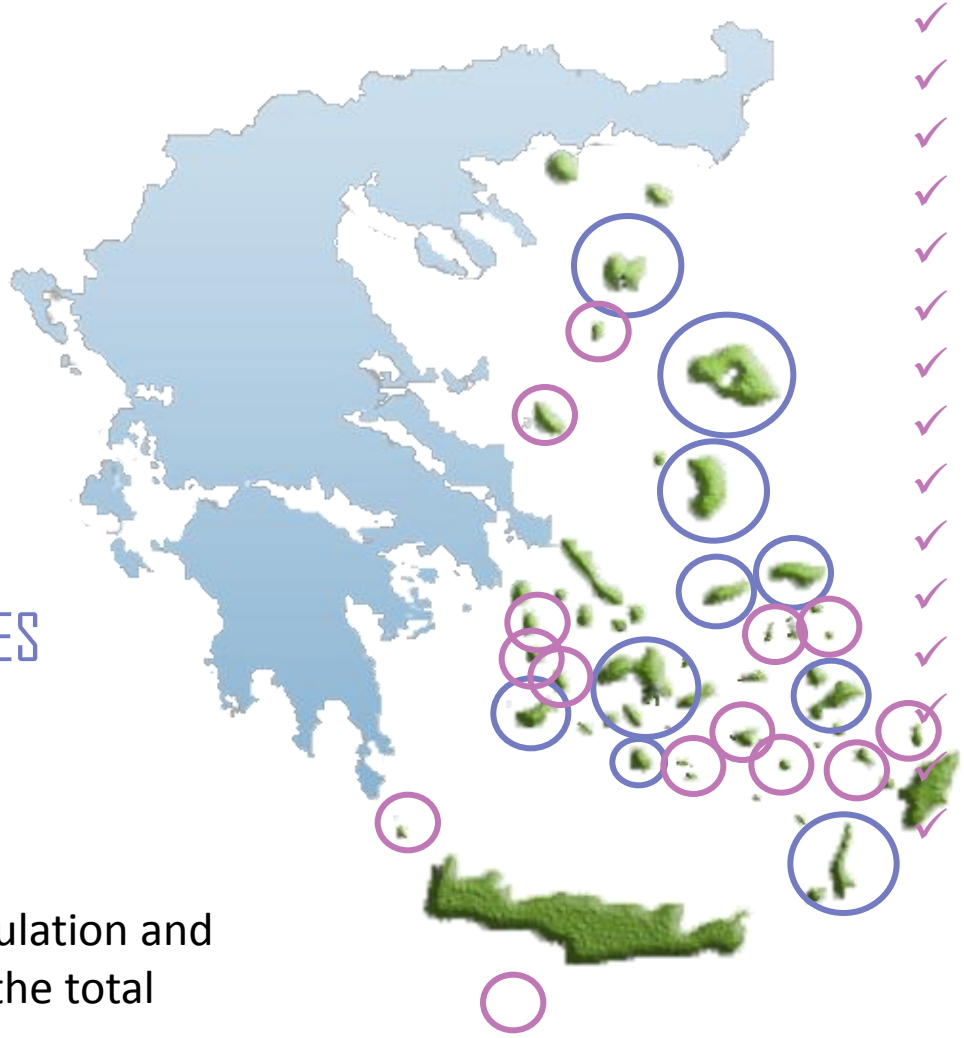
- 32 Electrical Systems (ES)
- Categorized by Average Peak Demand (last 5 years)
  - Large (>100MW) : 2 ES
  - Medium(> 5 ≤ 100 MW): 14 ES



- ✓ Paros
- ✓ Chios
- ✓ Mykonos
- ✓ Samos
- ✓ Syros
- ✓ Limnos
- ✓ Milos
- ✓ Ikaria
- ✓ Thira
- ✓ Karpathos
- ✓ Kos-kalymnos
- ✓ Lesvos
- ✓ Patmos
- ✓ Sifnos

NII Structure

- 32 Electrical Systems (ES)
- Categorized by Average Peak Demand (last 5 years)
  - Large (>100MW) : 2 ES
  - Medium(> 5 ≤ 100 MW): 14 ES
  - Small(≤ 5 MW): 16 ES



- ✓ St.Efstratios
- ✓ Agathonisi
- ✓ Amorgos
- ✓ Anafi
- ✓ Antikythira
- ✓ Arkioi
- ✓ Astypalaia
- ✓ Gavdos
- ✓ Donousa
- ✓ Ereikousa
- ✓ Kythnos
- ✓ Megisti
- ✓ Othonoi
- ✓ Serifos
- ✓ Skyros
- ✓ Symi

✓ Host 15 % of the Greek population and account for almost 14 % of the total national annual electricity consumption (~42.300 GWh/year)

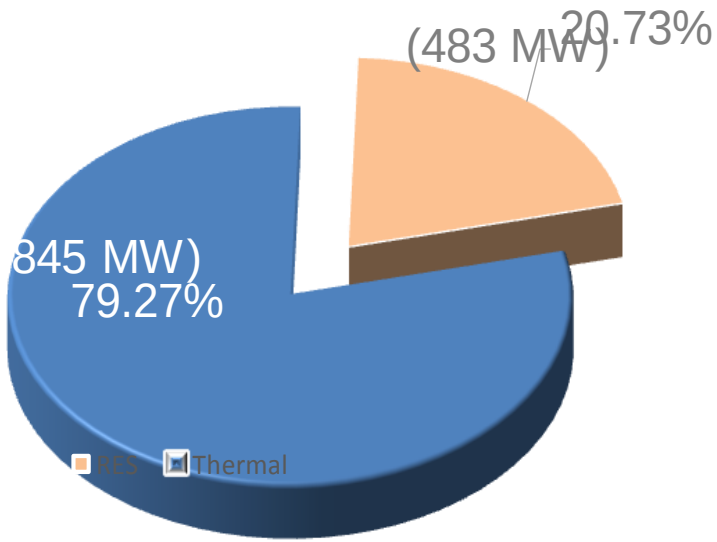
IN OPERATION AT NII

Total NII installed Power capacity 2328,14 MW

35 Conventional (Thermal) Stations 1845,3 MW

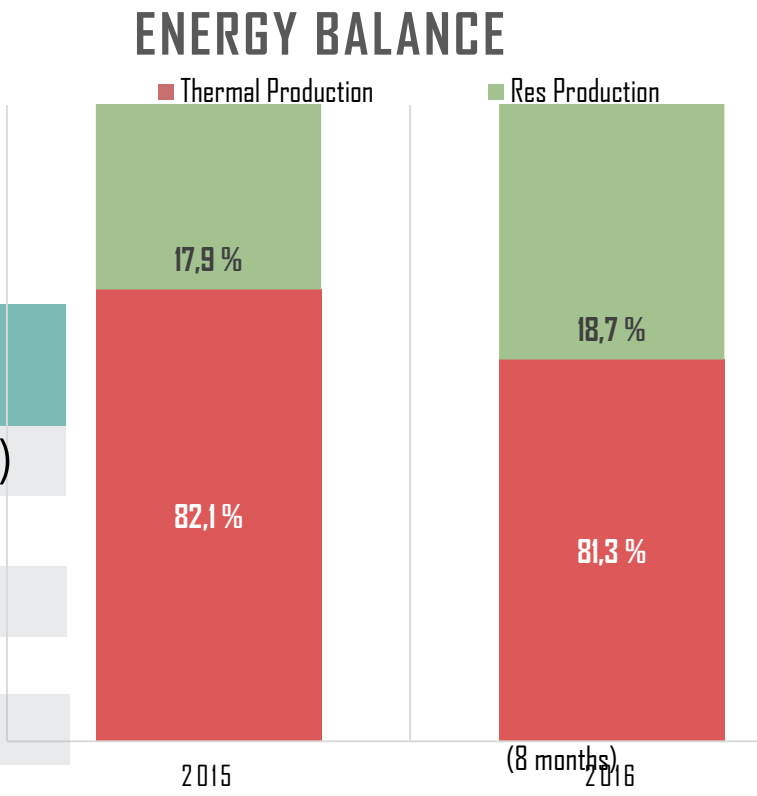
5098 RES Stations (482,84 MW)

- 97 Wind Parks (322,83 MW)
- 1758 PV Stations (135,98 MW)
- 3242 PV$_{roofs}$ (23,73 MW)
- 1 Small HydroElectric Station (0,3 MW)



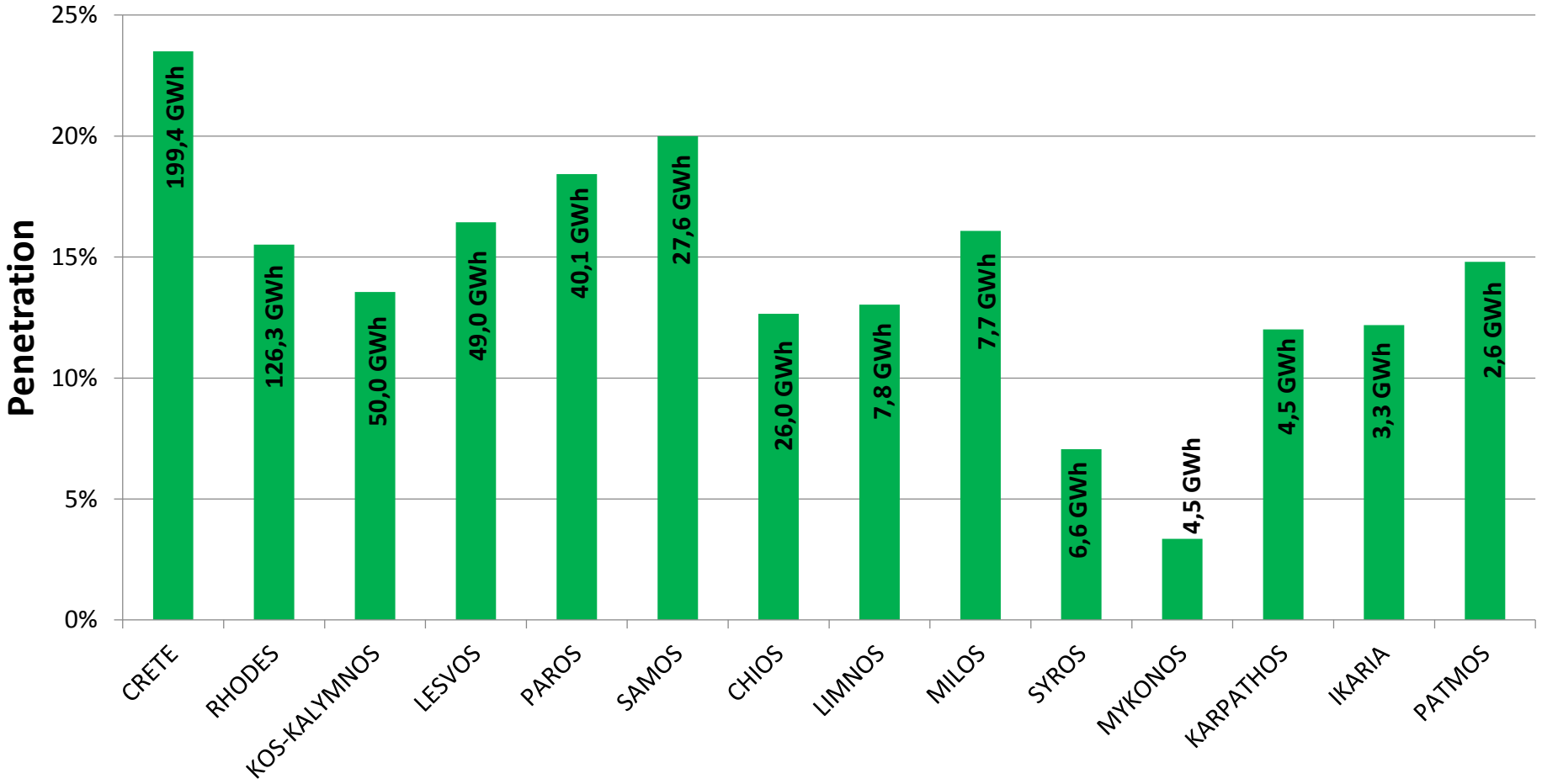
ENERGY BALANCE IN NII

The Energy Balance of NII		
	2015	2016 (8 months)
Total Production (GWh)	5.570,78	3.881,91
Thermal Production	82,1%	81,3%
RES Production	17,9%	18,7%
Average Variable Cost in NII	177,18 €/MWh	148,24 €/MWh



- Pool System Marginal Price in Mainland : 41,40 €/MWh

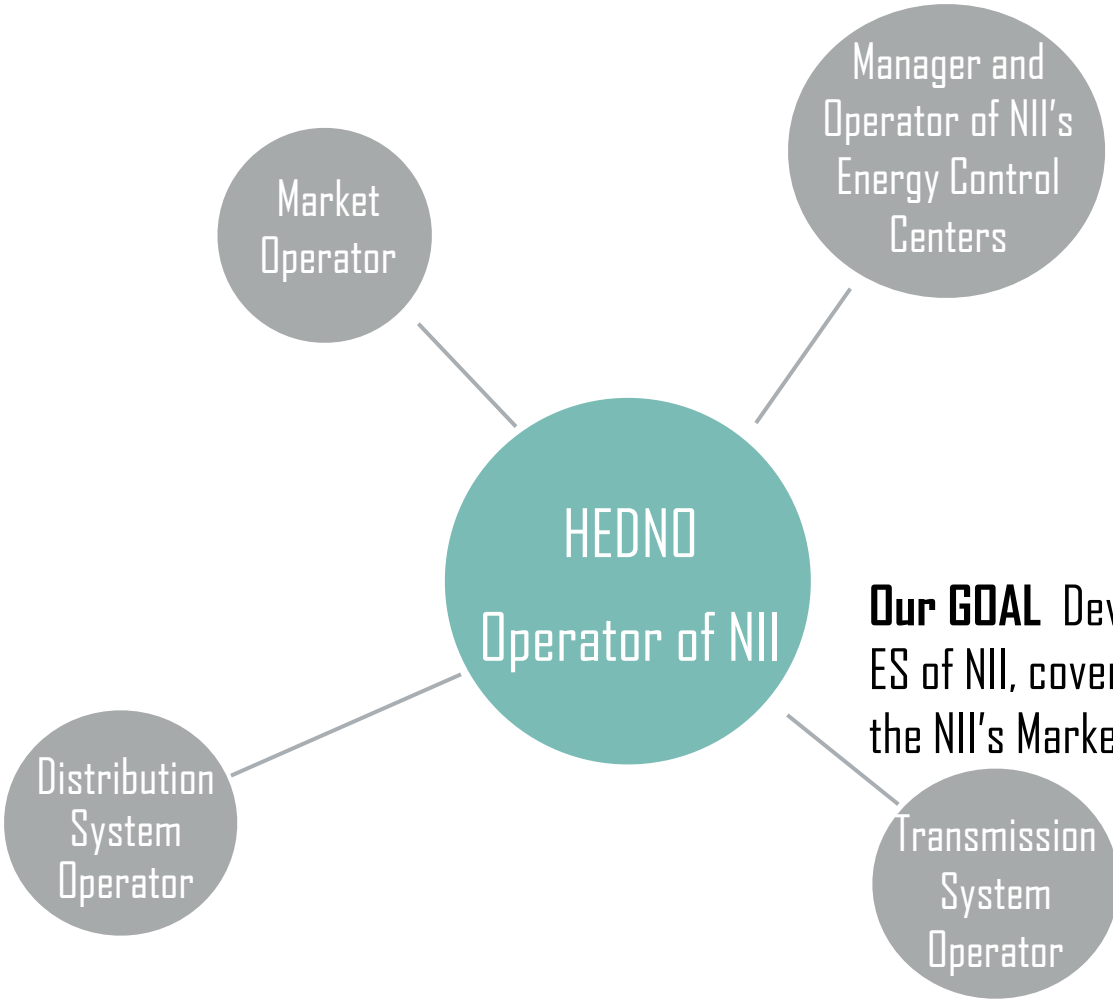
ENERGY BALANCE IN NII



Total RES Production in 2016: 1.058 GWh

Total RES penetration in 2016: 18,7%

HEDNO's ROLE AS NII's ELECTRICAL SYSTEM OPERATOR



Our MISSION

- Increase RES penetration in each ES of NII
- Reduce the operational cost of NII's ES
- Ensure uninterruptible electricity supply of prosumers

Our GOAL Develop the necessary infrastructure for the 32 ES of NII, covering the emerging needs of all participants in the NII's Market

HEDNO's major challenges in the NIIs

01 Islands of different size, population and distance from the Mainland, without easy access at any time especially by the sea.

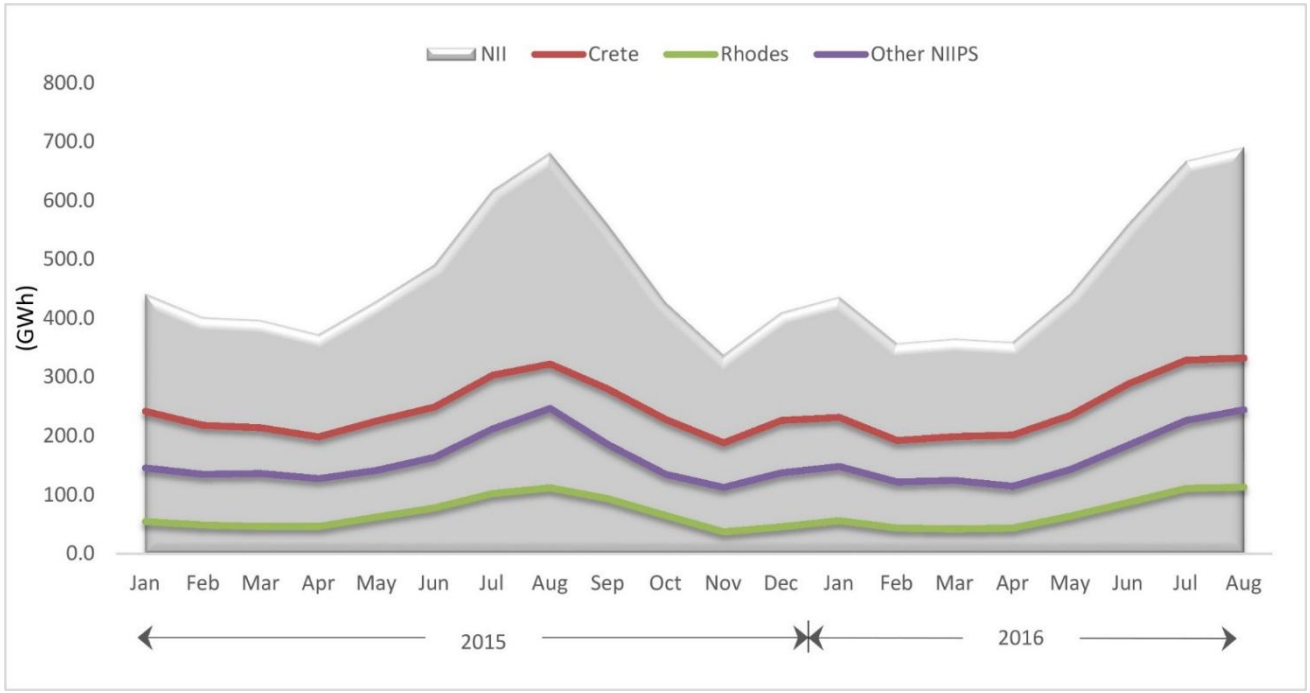
03 High potential for RES due to very good wind regimes and solar irradiation levels

02 Isolated ES, without energy exchange ability, with direct bearing on ensuring the availability of energy supply

04 Due to lack of interconnections with electrical systems of high inertia, the NII's ES potential problems of voltage and frequency stability

HEDNO's major challenges in the NIIs

05 High fluctuations of demand both on a daily and monthly basis.



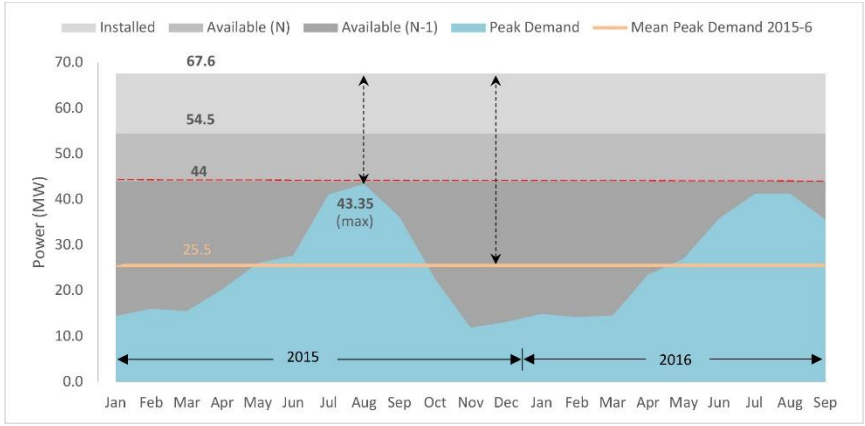
Monthly Load 2015 – 2016(Aug) on NIIPS

06 The max permissible RES penetration is limited by the above characteristics

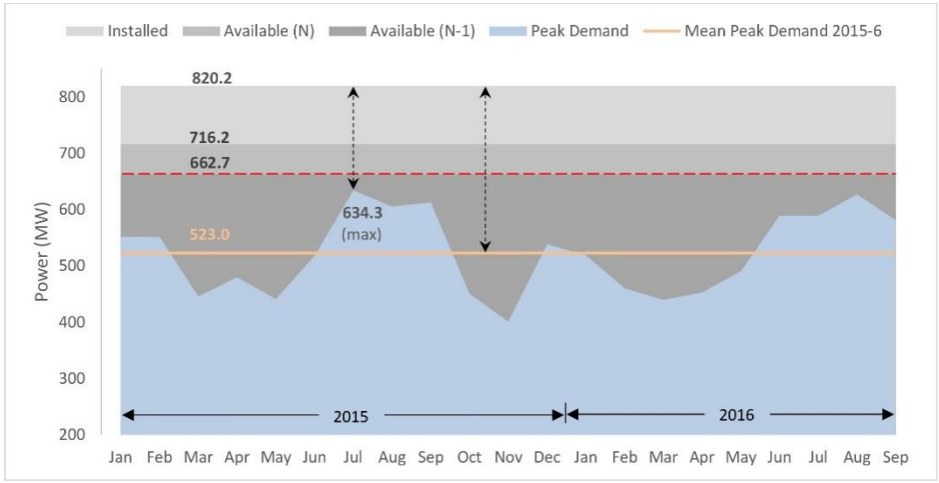
HEDNO's major challenges in the NIIs

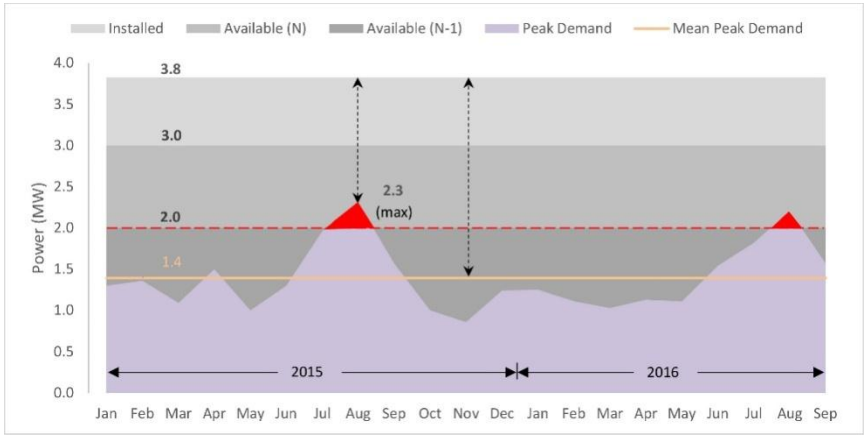
07 Large variations of Peak Demand among ES, between 100 KW to 650 MW

Medium ES: Mikonos



Large ES: Crete



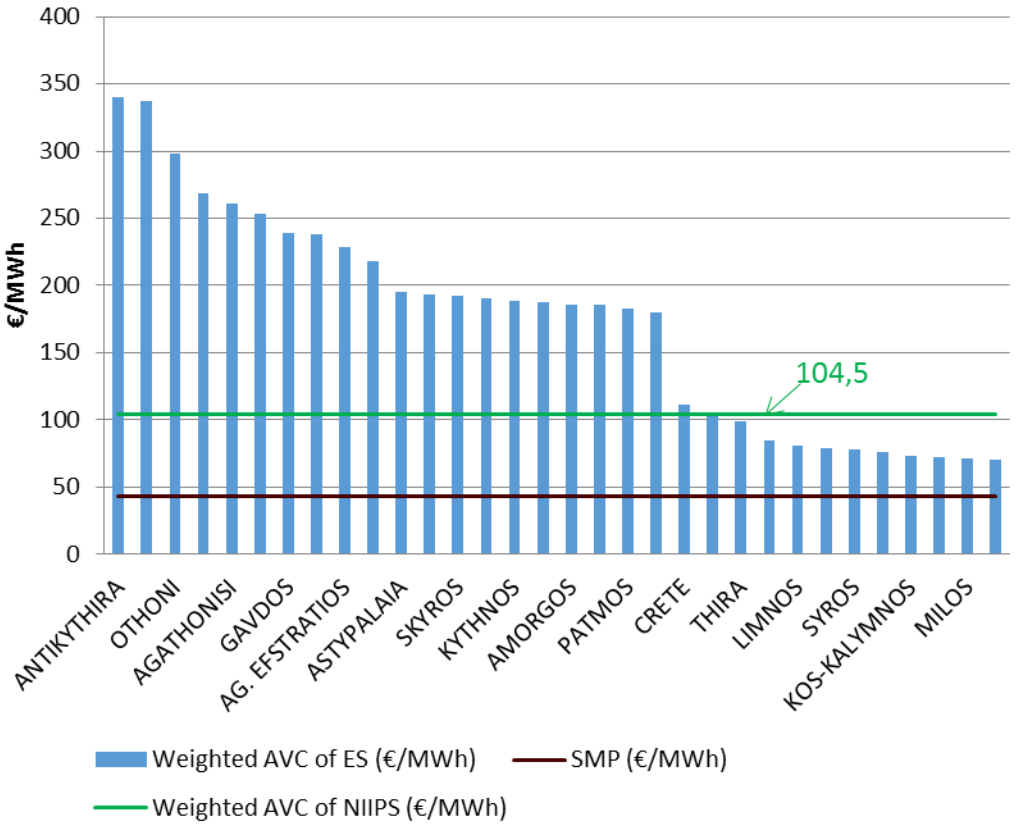


Small ES: Astypalea

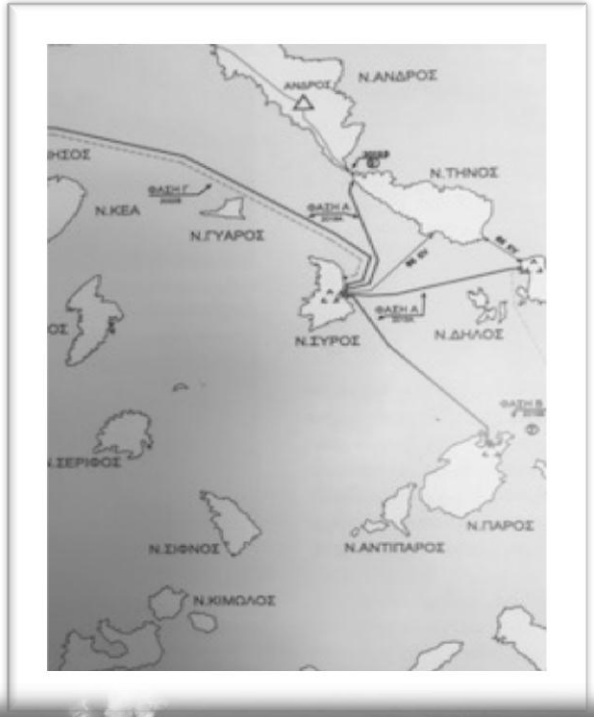
HEDNO's major challenges in the NIIs

NII's **Average Variable Cost** (**AVC**) is substantially higher (2-8 times) than the average System Margin Price (SMP) of the mainland Grid

Average Variable Cost (AVC) per NIIPS 2016



CONNECTIONS OF ES-NIIPS TO THE MAINLAND



HEDNO in cooperation with ADMIE (IPTO) and RAE is conducting feasibility studies for the interconnections of the NIIS to the mainland aiming at reducing the operational cost and increasing RES penetration

CONNECTIONS OF ES-NIIPS TO THE MAINLAND

A: In Progress

A1: Cyclades - 3 ES of NIIPS

- ES – Mykonos:
  - Mykonos
  - Dilos
  - Rinia
- ES – Syros:
  - Syros
- ES – Paros:
  - Paros
  - Naxos
  - Antiparos
  - Koufonisi
  - Sxinousa
  - Iraklia
  - Sikinos
  - Folegandros
  - Ios

A2: ES – Crete

- Main Connection with Attica:
  - DC underwater
  - 2x350 MW
  - 400 km
  - by 2023
- First Connection with Peloponnese:
  - AC underwater
  - 200 MVA
  - 150 km
  - by 2020

CONNECTIONS OF ES-NIIPS TO THE MAINLAND

B: Under Study - Interconnections of ES-NIIPS

B1: Interconnections via HV Underwater Cables

- ES–Thira (Islands: Thira, Thirasia) with ES-Paros and ES-Milos
- ES–Sifnos: (Islands: Sifnos) with ES-Syros
- ES–Milos: (Islands: Milos, Kimolos) with ES-Thira, ES-Sifnos and possibly ES-Serifos
- ES–Serifos: (Islands: Serifos) with ES-Syros

B2: Interconnections via MV Underwater Cables

- ES–Serifos: (Islands: Serifos) with ES-Sifnos
- ES–Anafi: (Islands: Anafi) with ES-Thira
- ES–Astypalea: (Islands: Astypalea) with ES-Thira

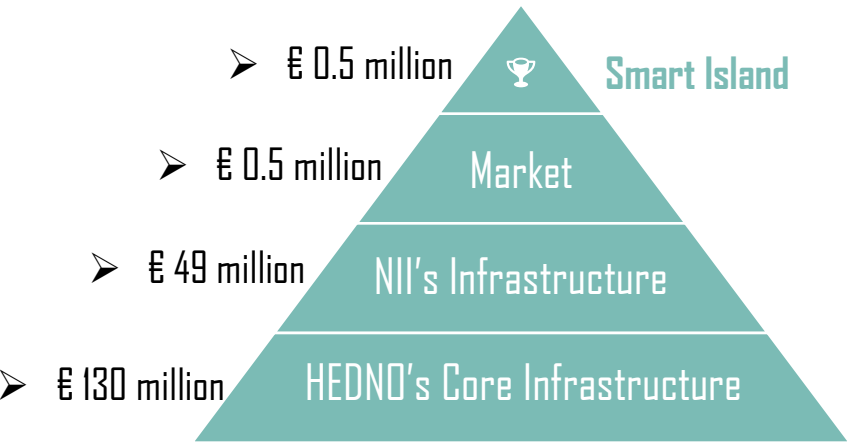
OUR STRATEGY FOR NII

- HEDNO, as NII's Electrical System Operator, is committed to implement in the course of the following years (up to 2020) all the necessary infrastructure through which Smart Islands will transform from vision to reality.

- The operation of the Greek islands is unique in Europe and Smart Grid technologies combined with the appropriate storage systems can ensure the optimization of the management of NII's ES.

- Compliance to the
  - ✓ **requirements of the NII code**
  - ✓ **European Committee's Decision for Greek NII**
  - ✓ **Greek Energy Regulatory Authority Decisions**

OUR STRATEGIC PLAN FOR NII



HEDNO's Core Infrastructure

- Further implementation of Smart Metering Systems
- Digitalization and Data Management through smart and integrated systems

Market Infrastructure

- IT Systems
- Methodologies,
- Procedures

NII's Infrastructure

- Metering Infrastructure
- Methodological Infrastructure
- Energy Control Centers (ECC) in Athens and Rhodes
- Energy Control Centers (ECC) in the remaining ES

Smart Island

- Design of pilot Smart Islands and formation of appropriate framework for the development and implementation of the project

The Smart Island Challenge

Design of a pilot Smart Island and formation of appropriate framework for the development and implementation of the project aiming at the proper operation and management of a pilot Electrical System of NII with very high RES penetration (annual energy penetration greater than 60% of the total demand of ES).

The objectives of this innovative project are:

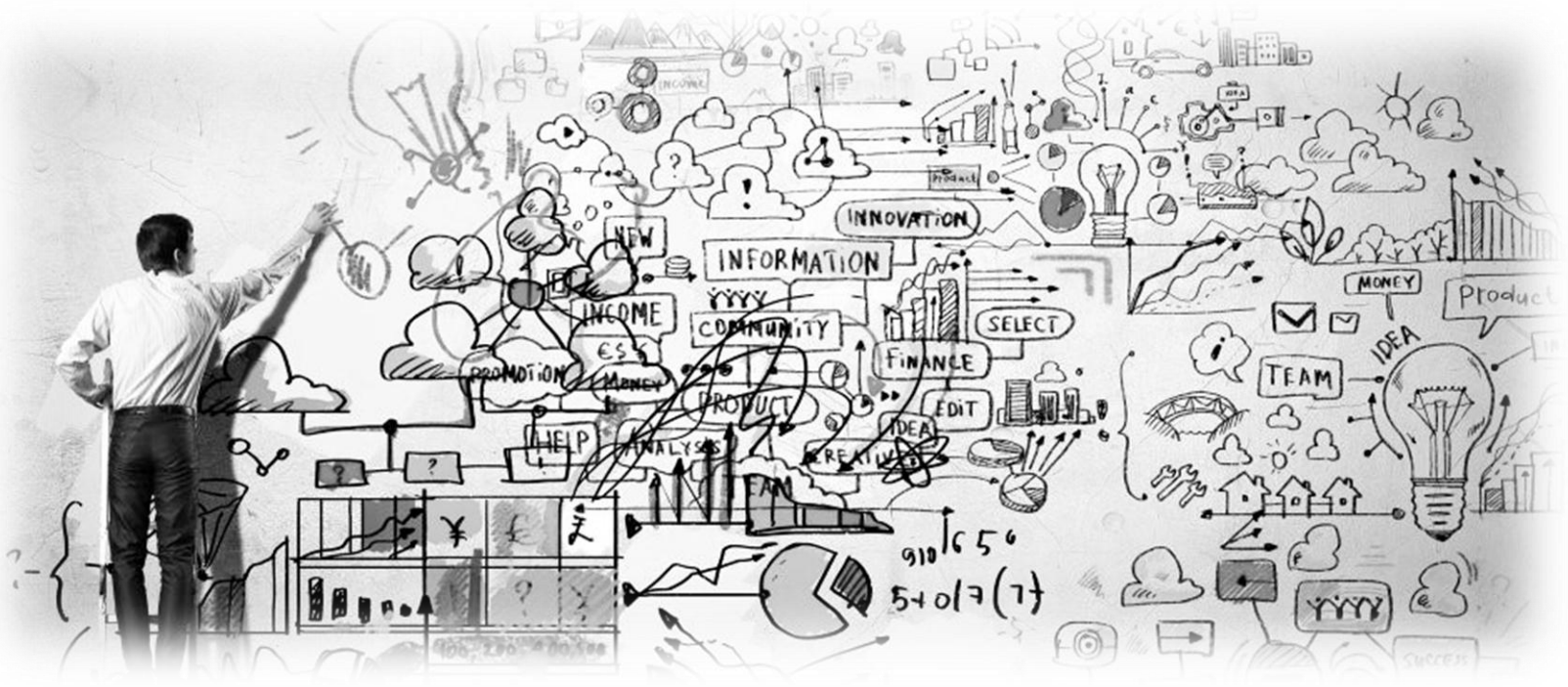
- Hybrid stations with RES and storage
- Sustainable solution
  - Does not increase the total cost in the island
  - Should be an attractive investment
- Ensure the security of power supply
- Minimize impact on thermal production
- New experiences for the Island Operator in order to replicate the solution in other islands

The Smart Island Challenge

New law 4495 (Special pilot projects in NII)

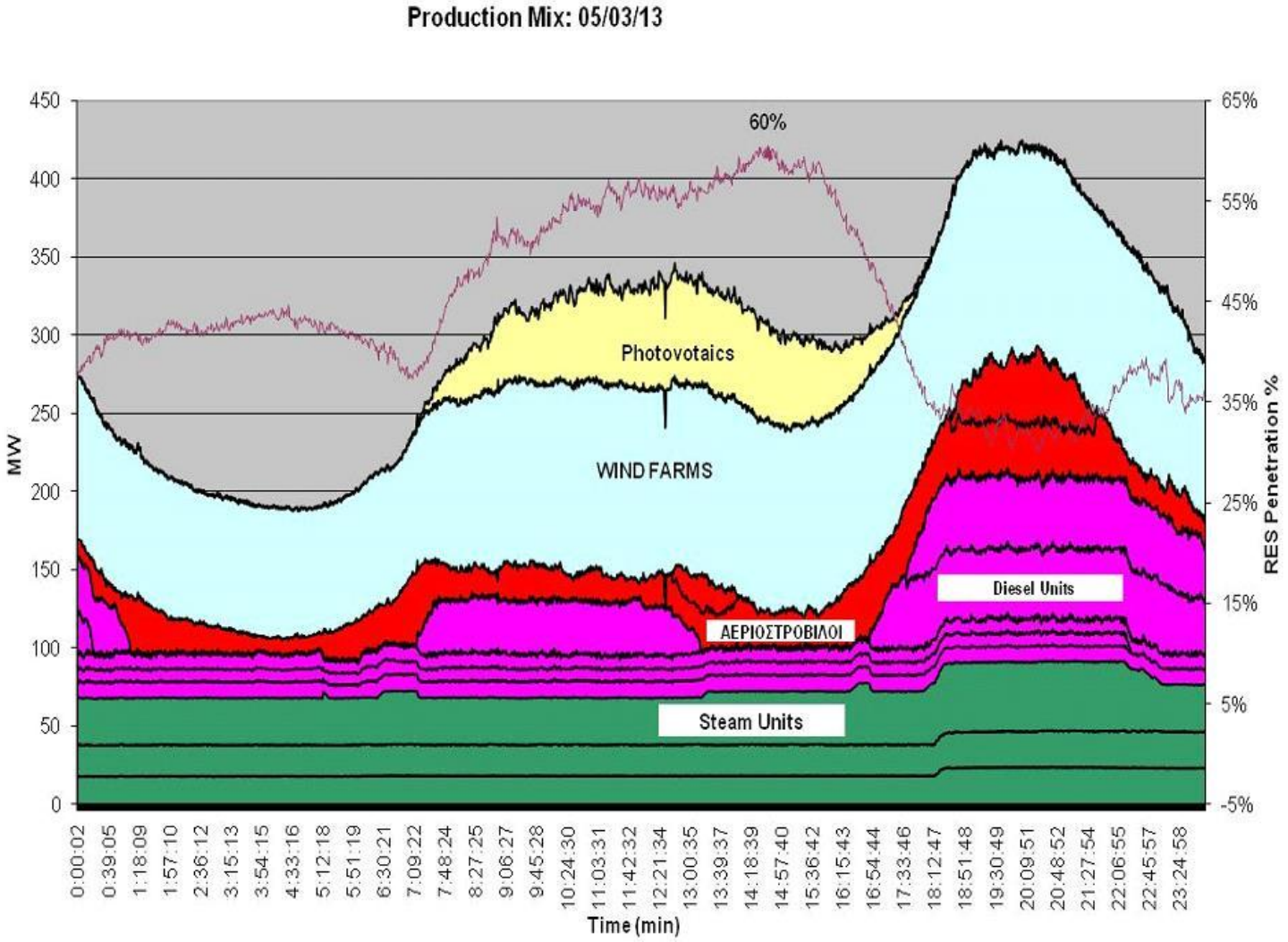
- HEDNO is responsible to suggest and promote the appropriate framework for the development of two pilot smart island projects in two different electrical systems.
- The pilot projects aim to increase RES penetration while ensuring proper operation and management of their Electrical Systems, reducing operational cost and supporting environmental protection.
- The pilot projects consist of hybrid stations with RES units combined with the appropriate storage and energy management system.
- HEDNO is conducting a study in order to select those two electrical systems and develop the proper framework for the tendering process that will be conducted by Regulatory Authority for Energy (RAE). The study is expected to be concluded and submitted to RAE by the end of April 2018.

R&D is a key….

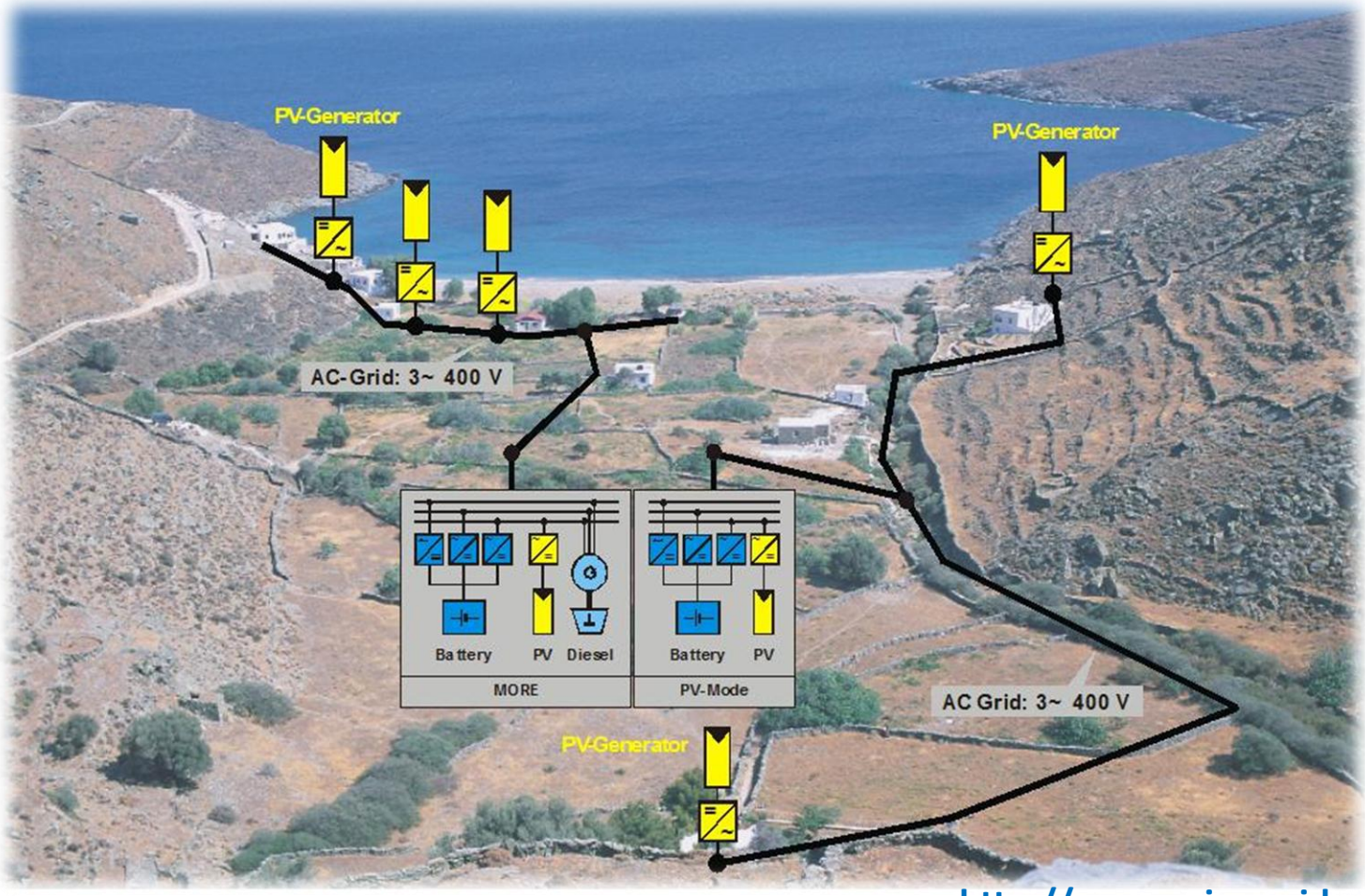

INNOVATION
NEW
INFORMATION
INCOME
COMMUNITY
SELECT
FINANCE
PROMOTION
MONEY
PRODUCT
EDIT
IDEA
HELP
ANALYSIS
TEAM
IDEA
MONEY
Product

R&D projects in the Greek Islands

- Kythnos (1982) Operation of the first Wind Park in Europe (5x20kW)
- Kythnos(1983) Operation of a 100 kW PV system with Battery storage
- Kythnos (2000) Operation of a fully automated power system with 500kW battery storage and a 500kW Wind Turbine
- Kythnos (2001) Operation of a Microgrid electrifying 12 houses with intelligent autonomous Load Control
- Crete (2003) Development of advanced control software system for isolated systems with high RES penetration
- Ikaria hybrid power station: Consisting of 1.05 MW small hydro, 3MW pumped storage and 2.7MW wind farm (*Almost completed*)
- TILOS: Small Hybrid station (Wind Turbine, PV and battery storage) (on-going)
- Several smaller RD&D projects



Crete Power Production – 60% hourly RES penetration



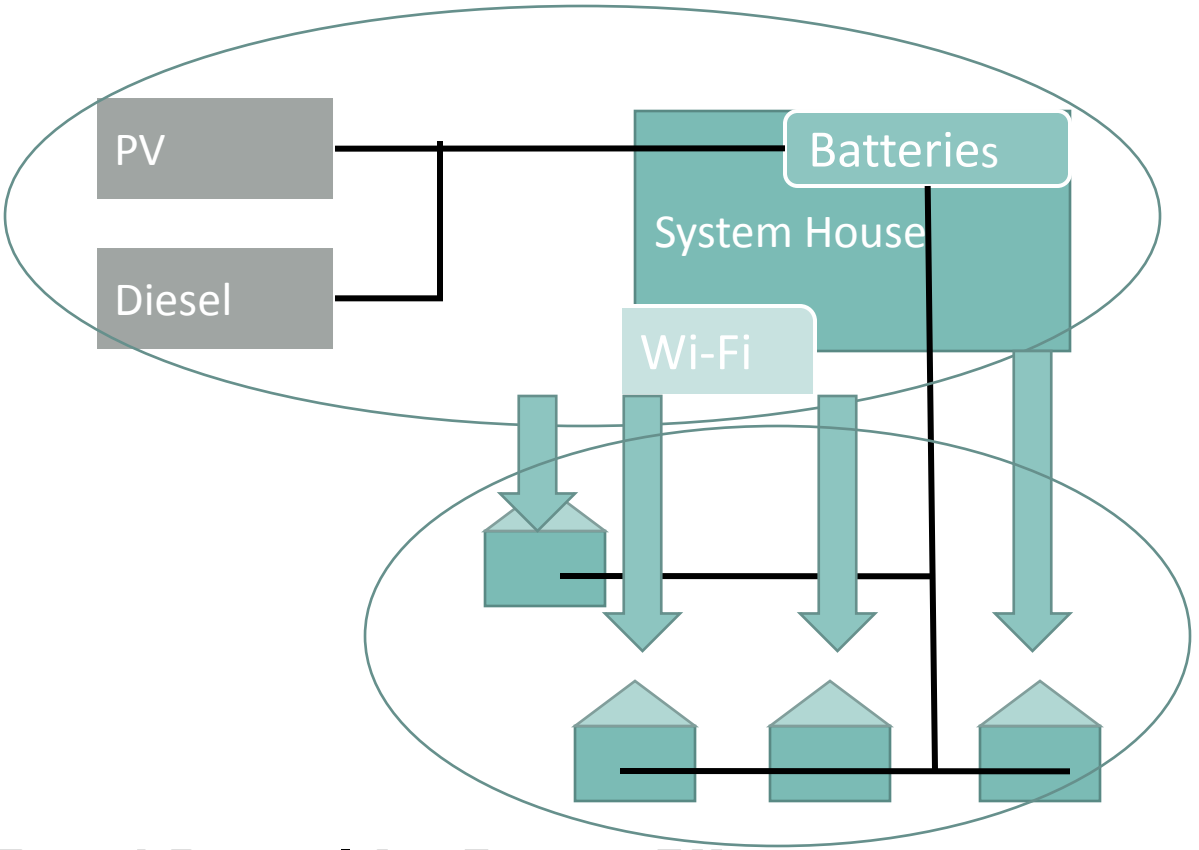
http://www.microgrids.eu

Kythnos Microgrid of 12 houses comprising PVs and Batteries (52 kWh), 9 kVA Diesel (only back-up), flexible loads (1-2 kW irrigation pumps), Intelligent Load Controllers


MORE
SMA

Step 1: The agents embedded in Intelligent Load Controllers identify the status of the environment (available energy)

Step 2: The agents negotiate on how the share the available energy without central coordination



Decentralized MAS Based Control for Energy Efficiency

"Microgrids: Architectures and Control", Editor Nikos Hatziargyriou, IEEE-Wiley&Sons, 2014

THINKING AHEAD

Actions for significant increase of RES penetration in NIIPS

- ❑ Advanced Energy Control Centers
- ❑ Implementation of storage
- ❑ Deployment of Dispatchable RES
- ❑ Demand Side Management
- ❑ Integrated solutions for very small NIIPS

Requirements

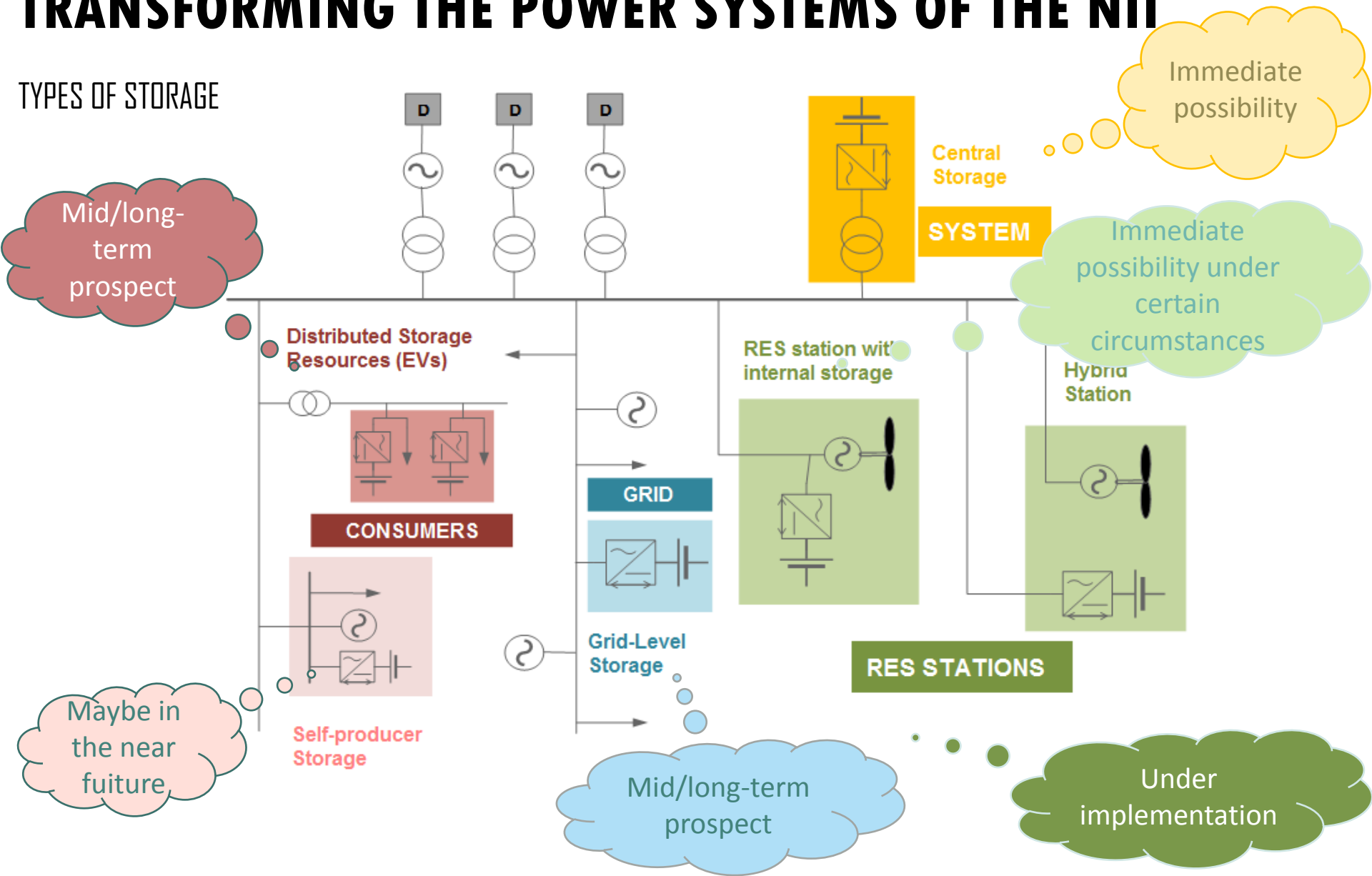
- Establishment of necessary legislative and financial framework
- Technical, operational and feasibility studies
- Social inclusive solutions to be endorsed by the local actors
- Funding for the necessary investments

Benefits

- Significant increase of RES penetration (more than 50%)
- Reduction of thermal operating cost
- Maintain overall production cost
- Maximize environmental benefits
- Lighthouse projects to develop know-how
- Explore potential for replication and upscale of innovative solutions
- Development of local economies

TRANSFORMING THE POWER SYSTEMS OF THE NII

TYPES OF STORAGE



THANK YOU