Cabo Verde: 100% RE Project

Build a safe, efficient and sustainable Energy Sector without dependence on fossil fuels

ECREEE

Praia, Cabo Verde

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OUTLINE

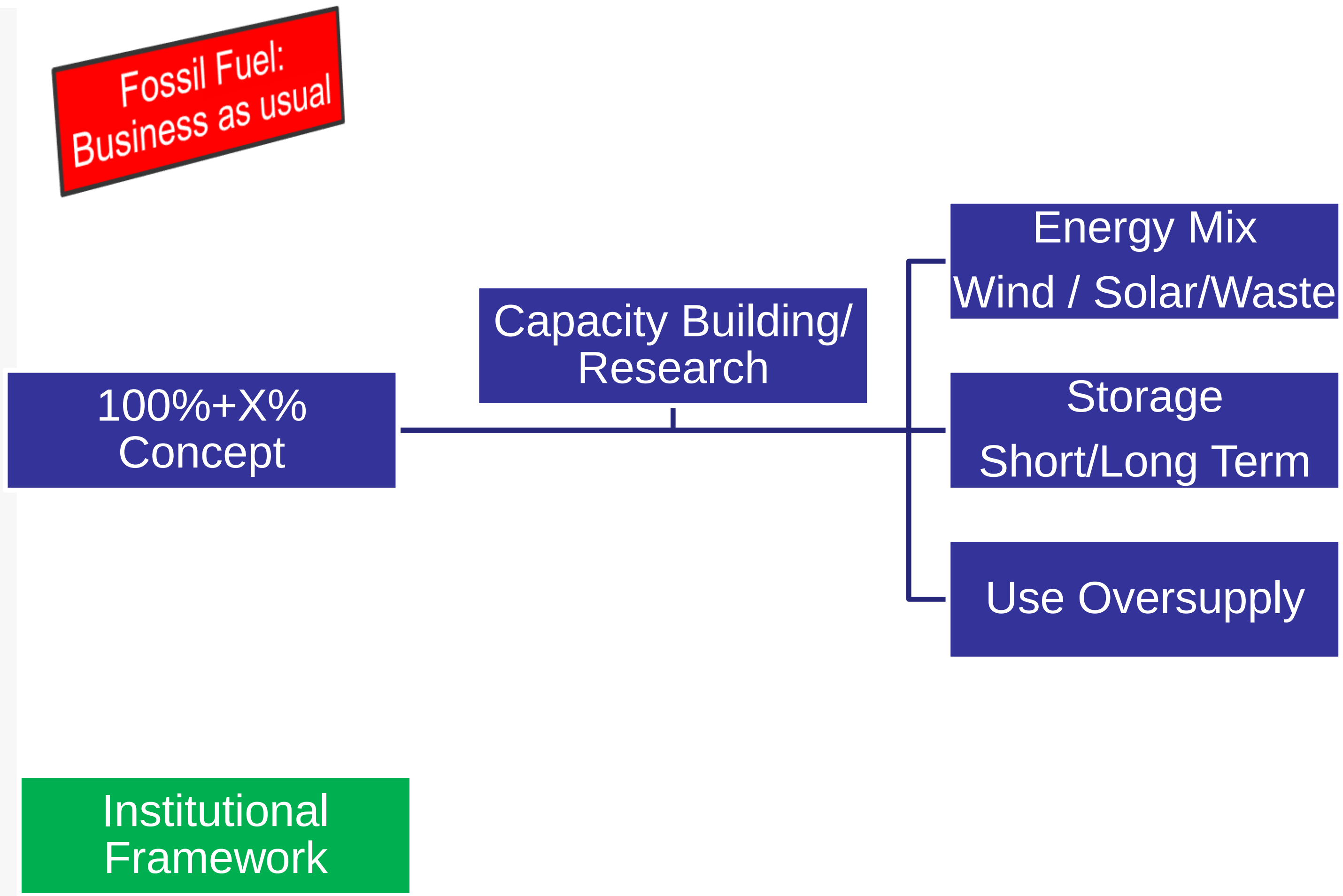
Fossil Fuel: Business as usual

100%+X% Concept

- Capacity Building/ Research
- Energy Mix
  Wind / Solar/Waste
- Storage
  Short/Long Term
- Use Oversupply

Institutional Framework

OUTLINE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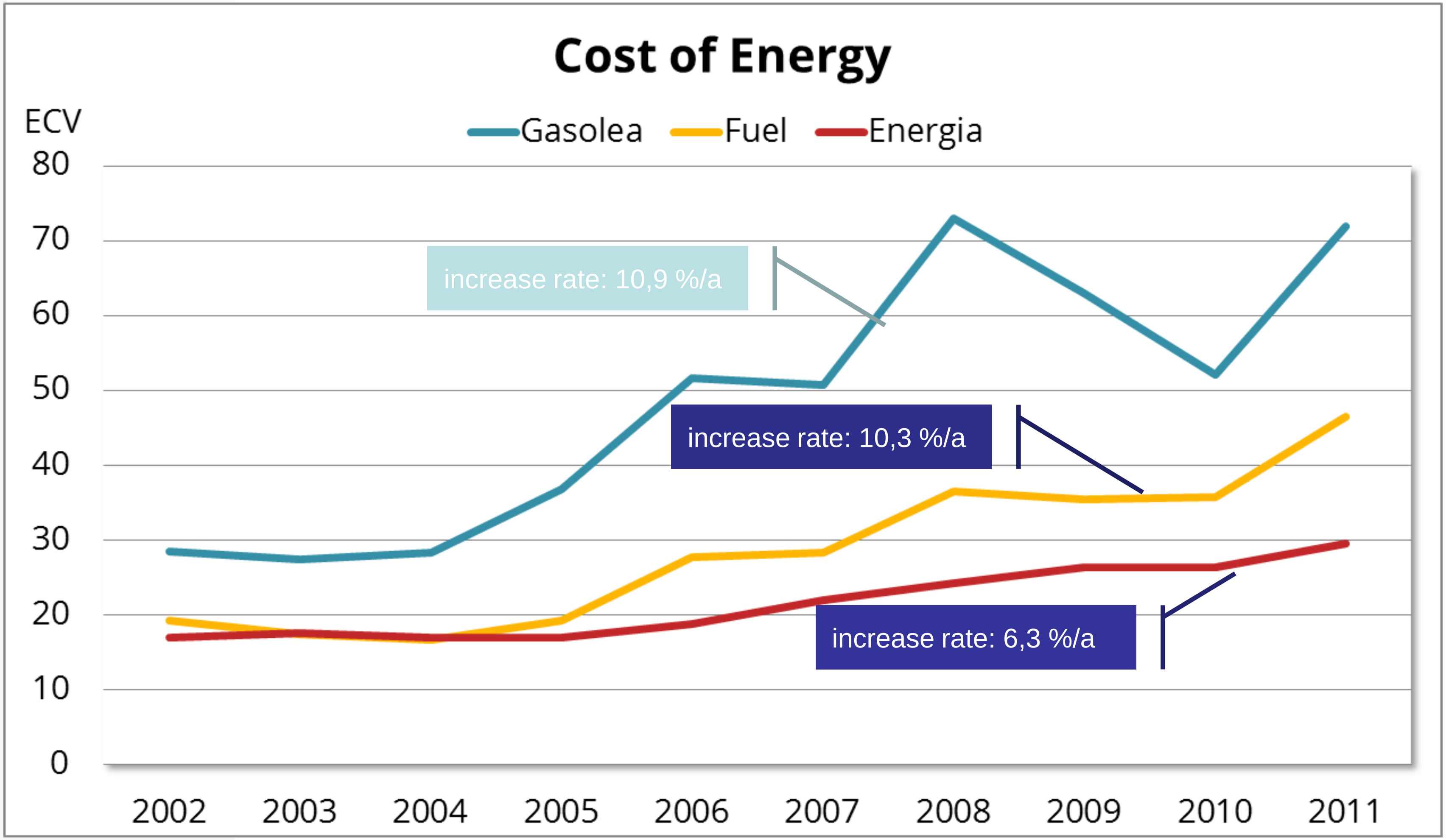
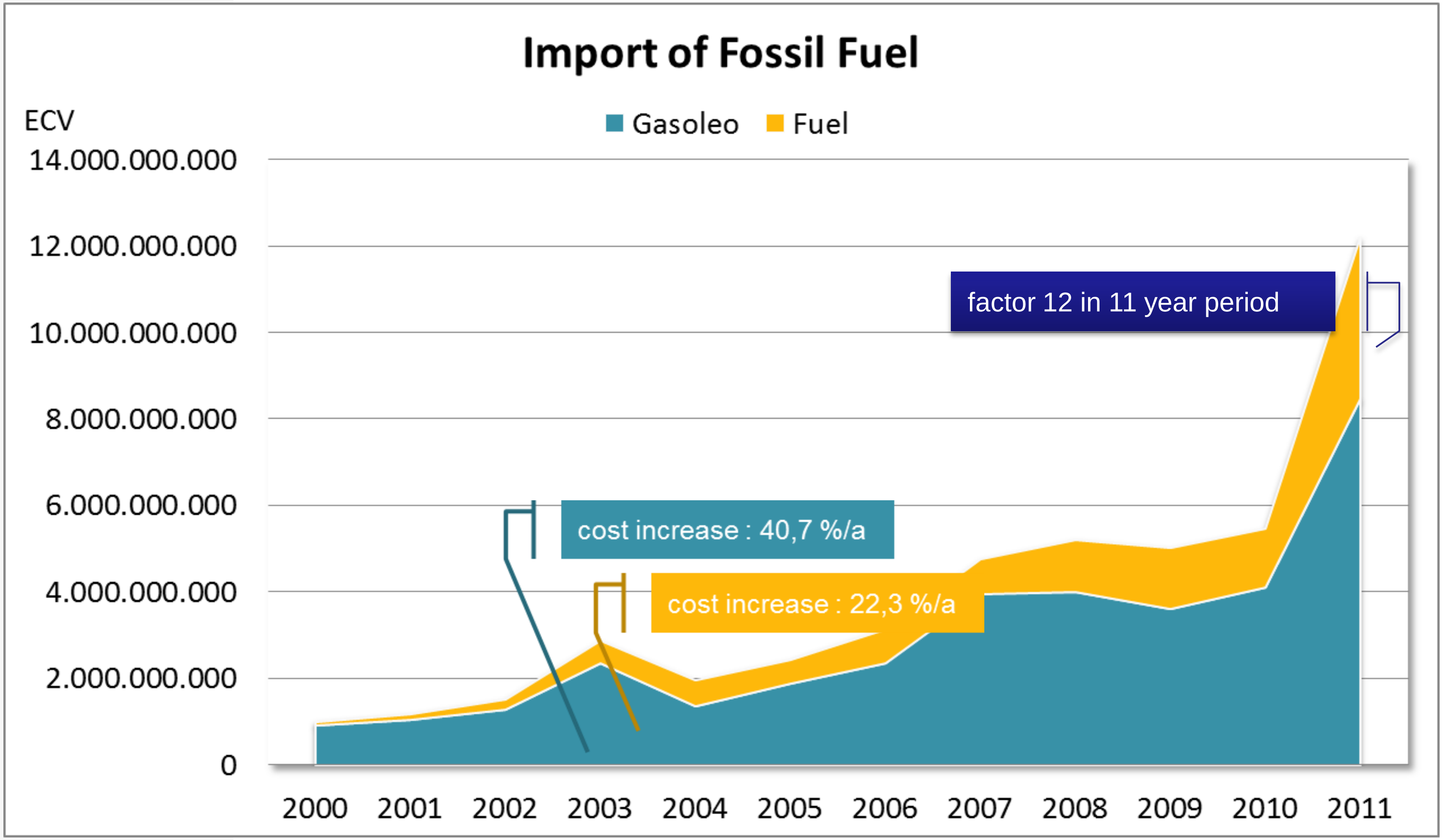
Fossil Fuel: Evolution of the Energy Cost



source
tables “Energia Nacional”

Fossil Fuel: Imports Evolution



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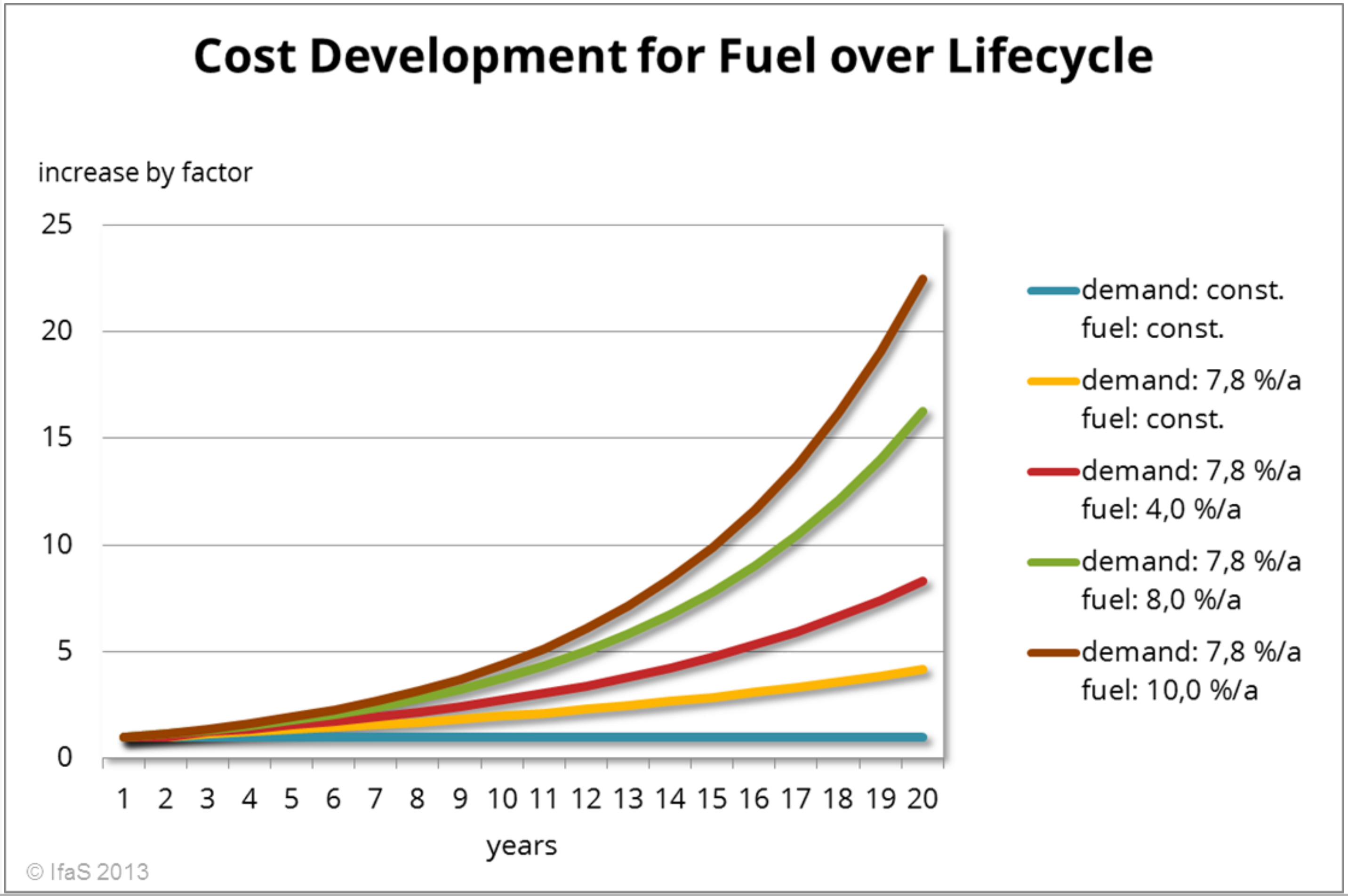
Fossil Fuel: Cost Development

If the power demand and fossil fuel price increase would continue for the decade to come, the import expenditures would increase by a factor of 18 until the year 2022

assumptions
- average increase rate for fuel: 10,3 %/a (from historic values 2002-2012)
- demand increase derived from Gesto's figures for 2020



Fossil Fuel: LCOE

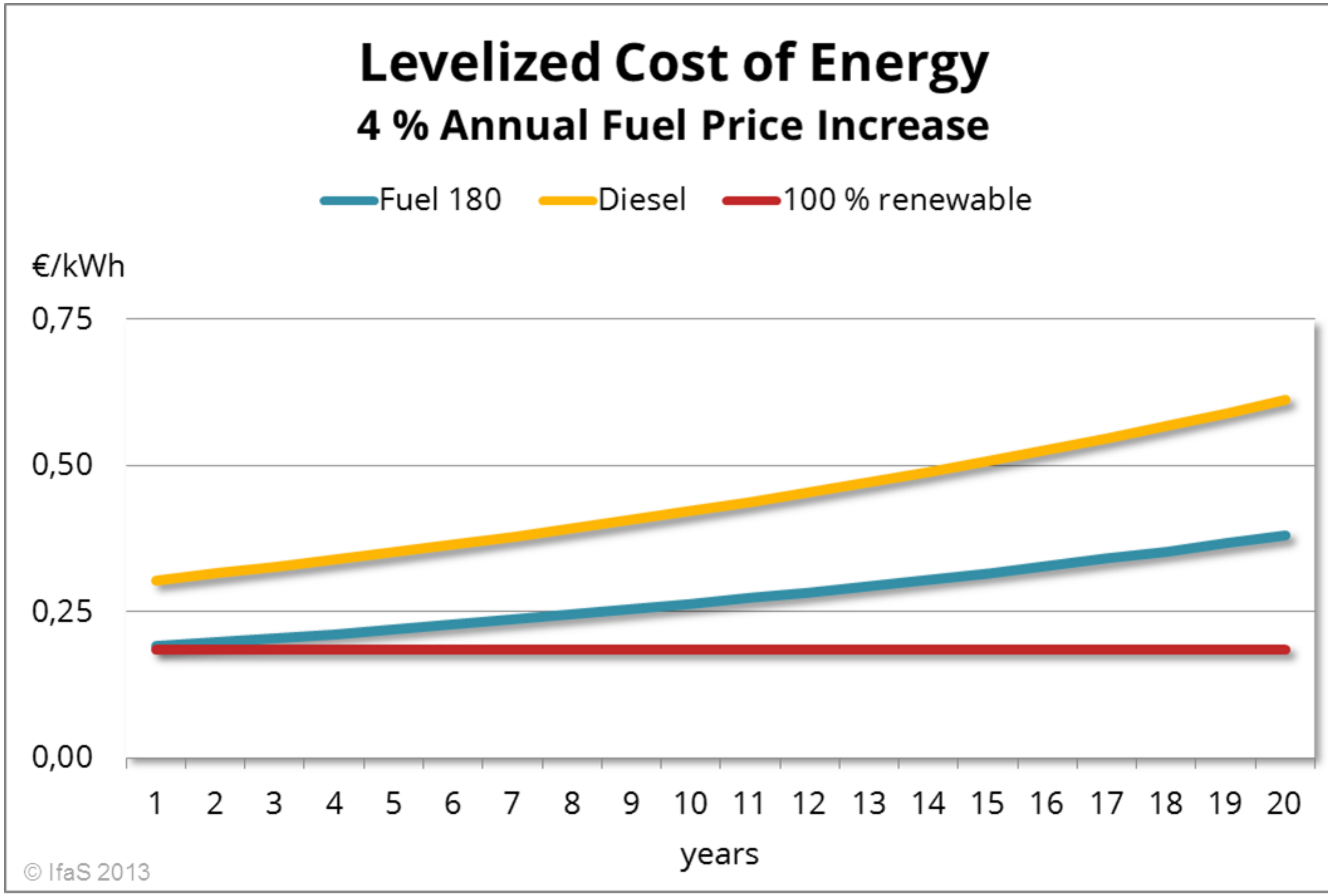
assumptions
- investment figures from Gesto study
- efficiency figures by fuel consumption and power production (Sal)
- fuel cost for 2012

LCOE		
	Fuel 180	**Diesel**
investment	**1.066 €/kW**	**1.066 €/kW**
interest	5 %	5 %
duration	20 a	20 a
annual capital cost	**86 €/a**	**86 €/a**
operation & maintenance	5 %	5 %
annual operational cost	**53 €/a**	**53 €/a**
service time	6.000 h/a	6.000 h/a
efficiency	38,6 %	33,3 %
fuel energy density	11,1 kWh/kg	9,7 kWh/l
fuel cost (actual)	0,73 €/kg	0,91 €/l
annual fuel cost (actual)	**1.017 €/a**	**1.682 €/a**
total annual cost (actual)	**1.156 €/a**	**1.821 €/a**
levelized cost of energy	**0,1927 €/kWh**	**0,3035 €/kWh**

Fossil Fuel: Levelized Cost

assumptions
- fuel cost starting with fuel cost of 2012

- HFO 180 cost 0,73 €/kg
  Diesel cost 0,91 €/l



Fossil Fuel: Levelized Cost

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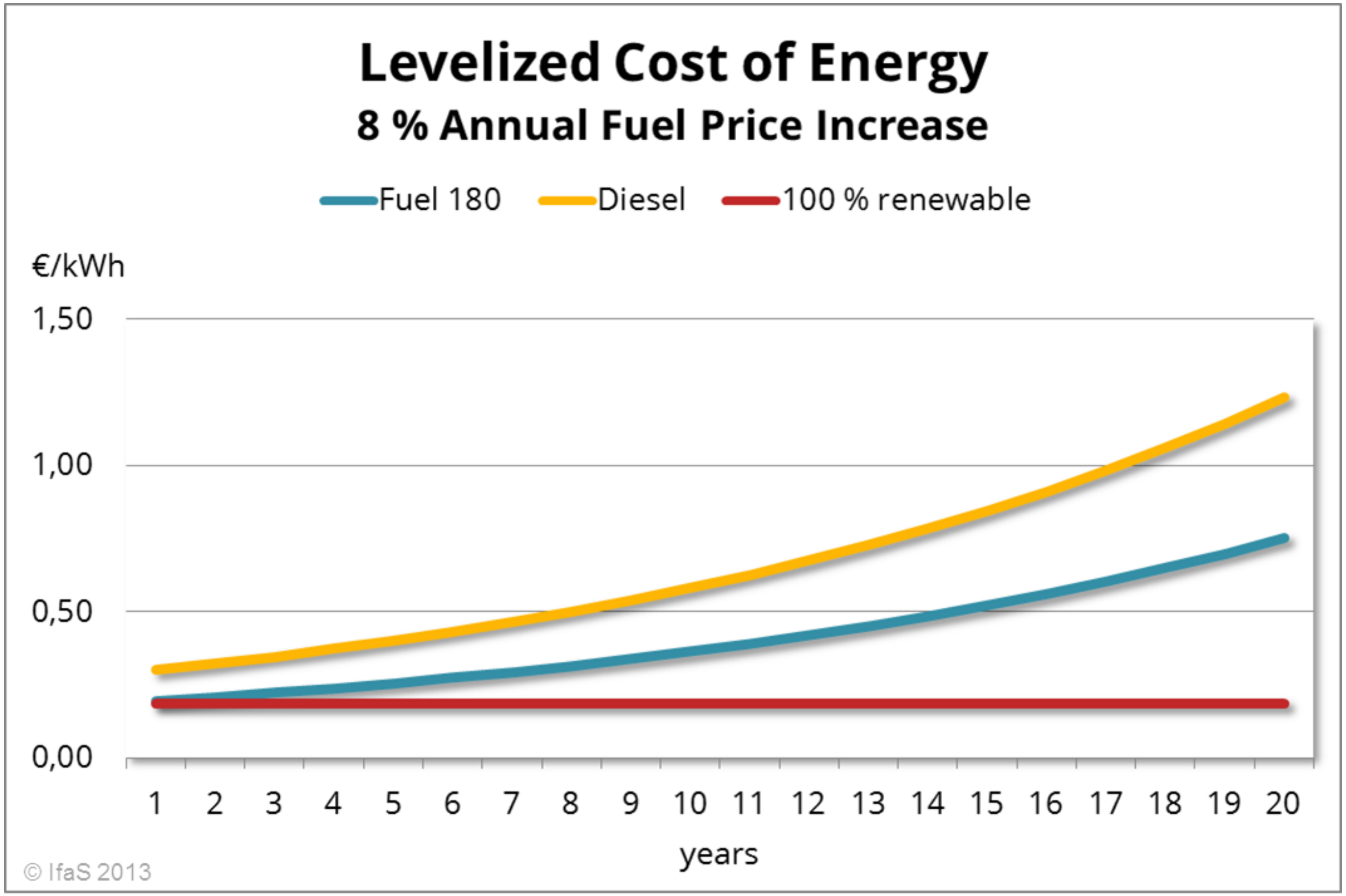


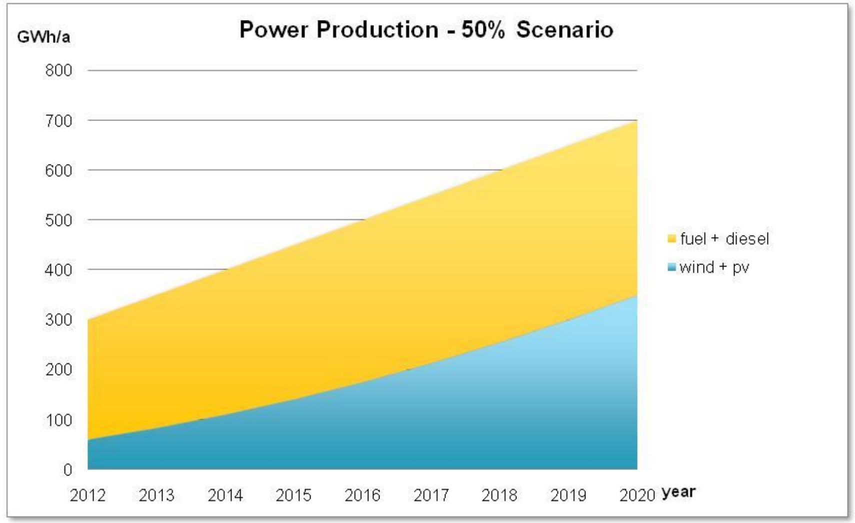
Scenario 50% RE: Power Production/ Costs

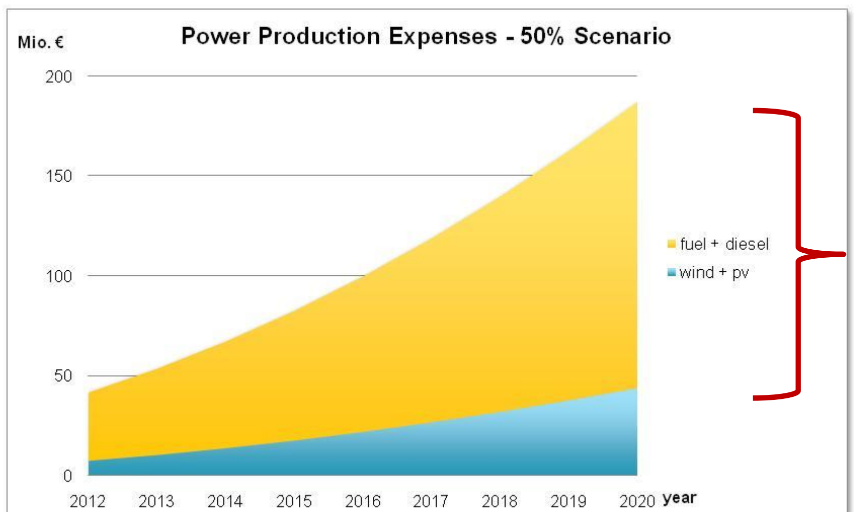
Assumptions

PV 3.400 €/kW
Wind 2.200 €/kW

Thermal Group 1.000 €/kW
Efficiency 30 %
Fuel Cost (act.) 0,71 €/l
Diesel Cost 1,09 €/l
Increase rate 15 %/a
8,5 %/a

Electr, Prod. 300 → 700 GWh/a
RE 20 → 50 %
Timeframe 2012 → 2020



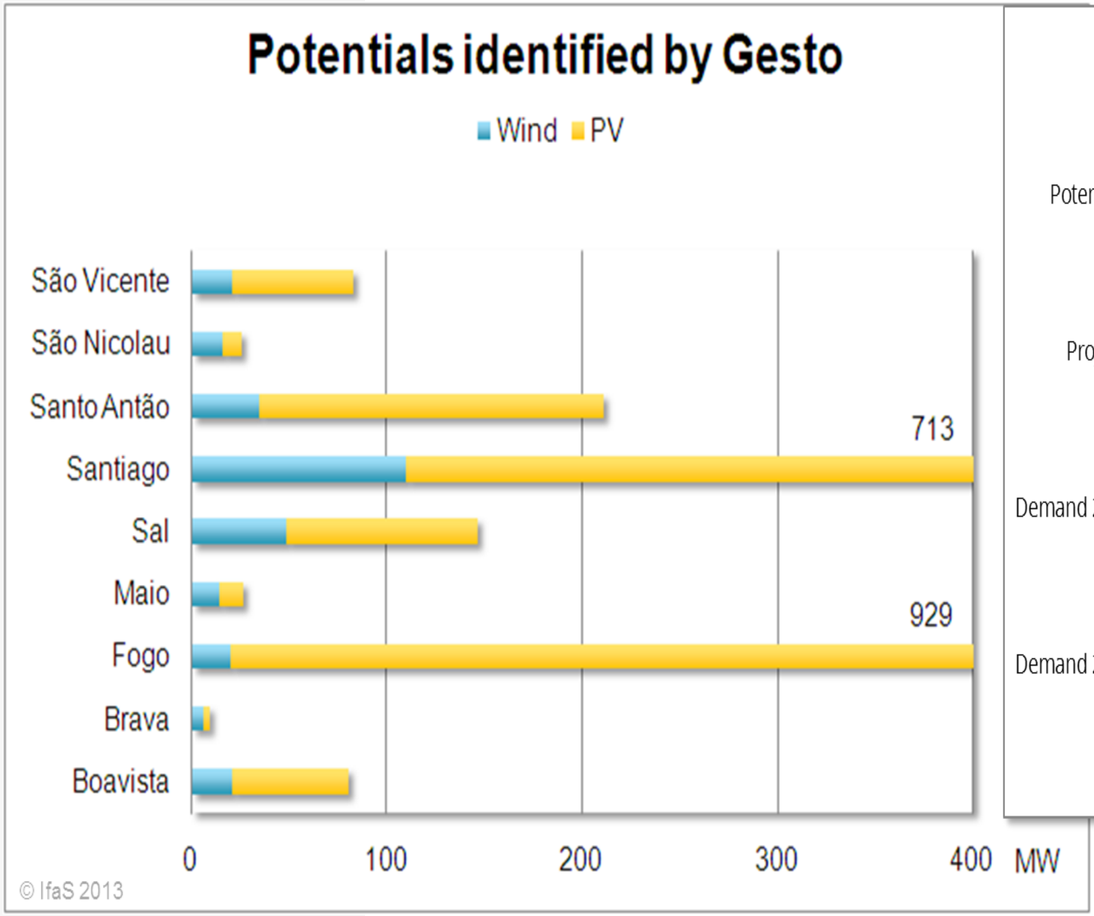


Results:

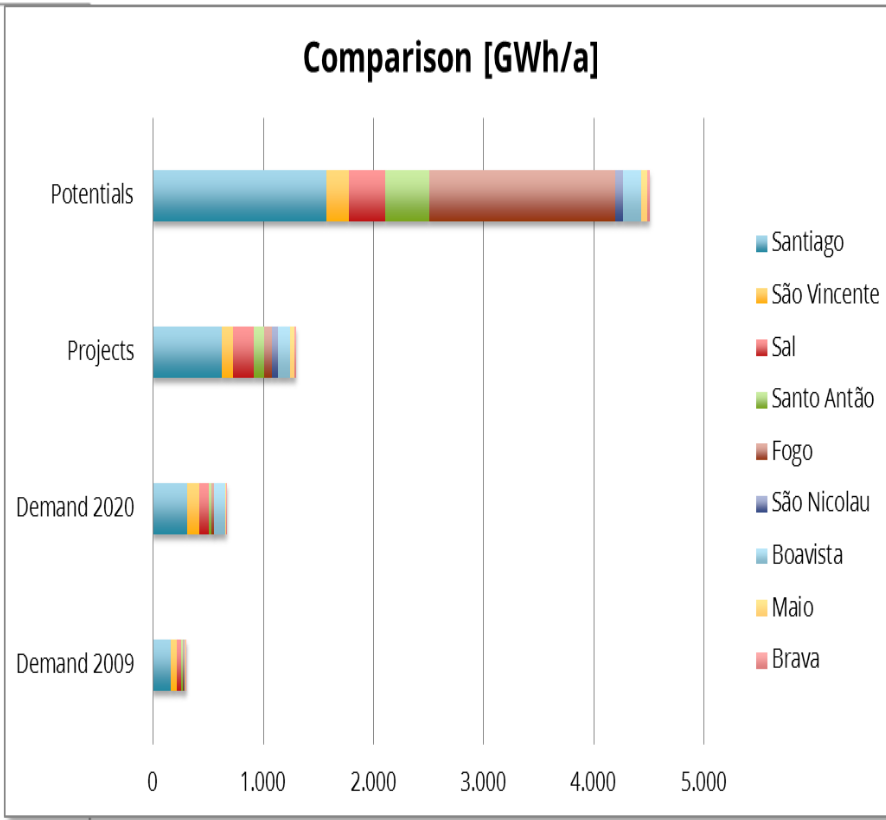
- **Pressure on Balance of Payment**
- **High domestic electricity and water prices**

Renewable Potentials: Wind /Solar

Potential by Island



Cape Verde: demand vs potential

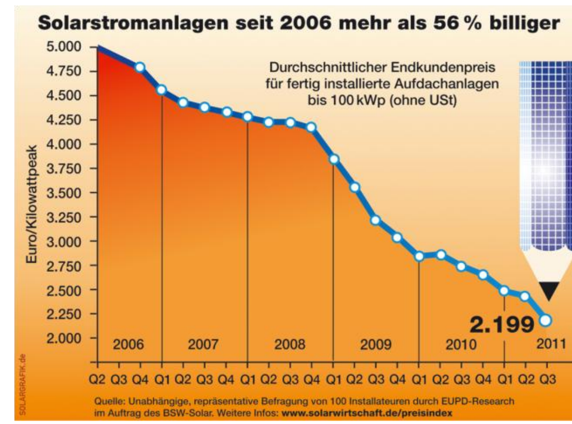


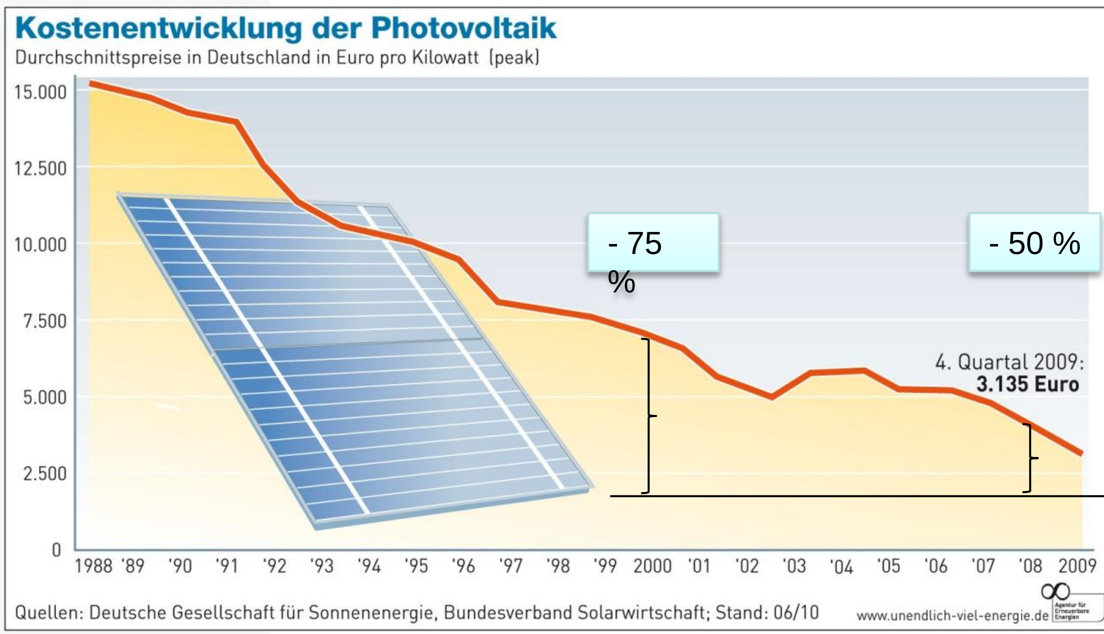
source: Gesto

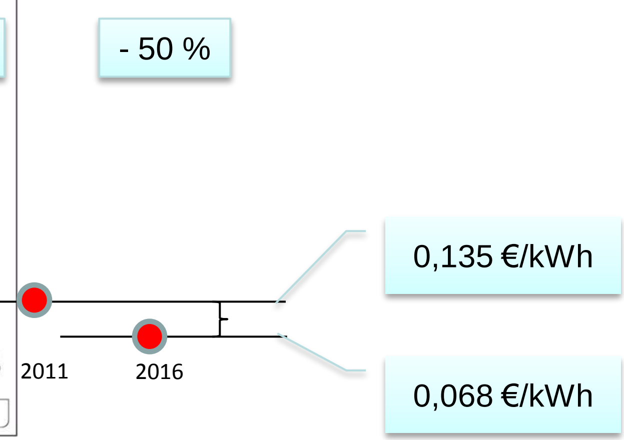
Decrease in Photovoltaic Price

Cost Decrease for Photovoltaic Systems

- since 2000 - 75 %
- since 2008 - 50%
- until 2016 - 50% - on top on 2012 level

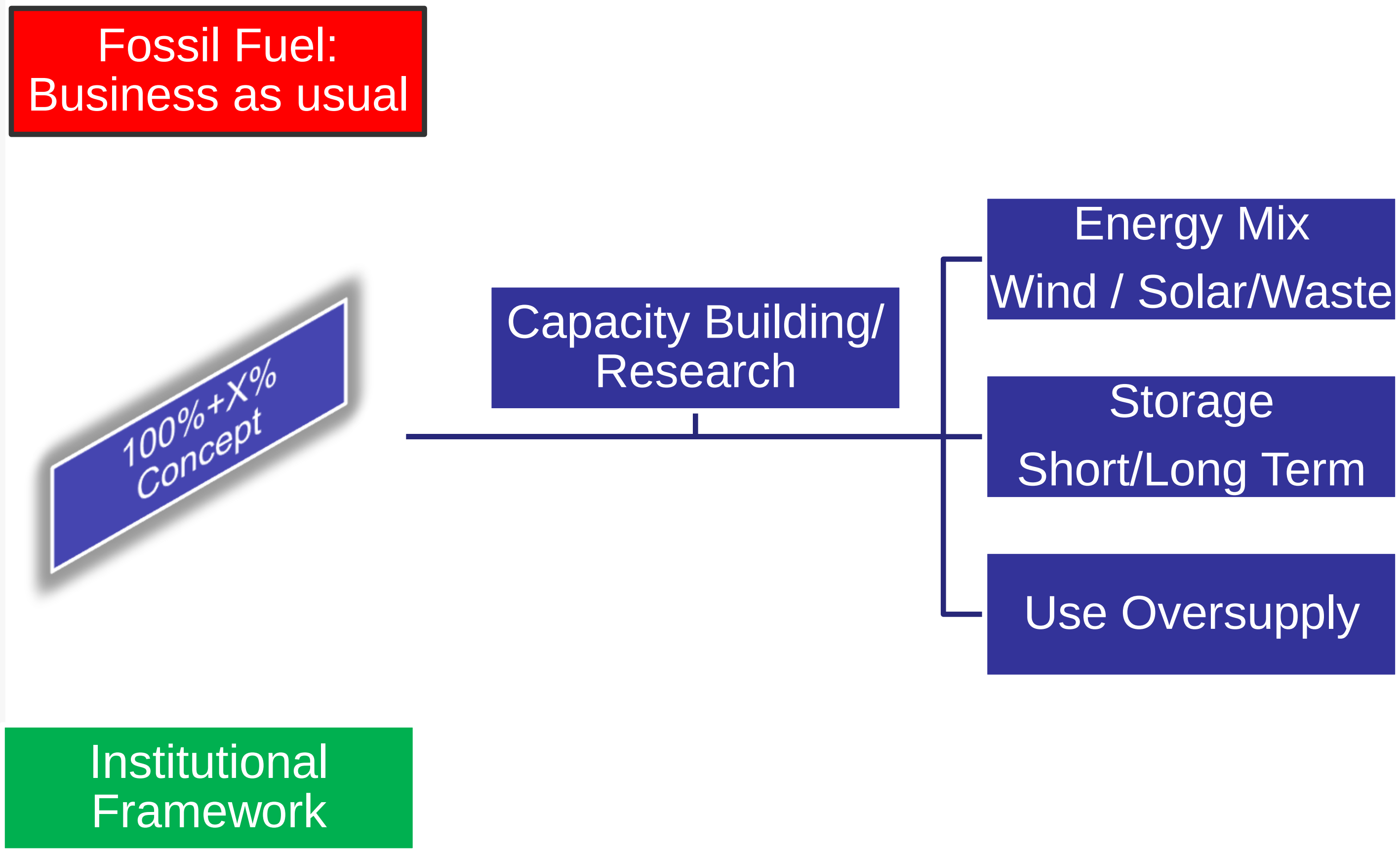






Source: Agentur für Erneuerbare Energien, BMU

100% + X% Concept



100% RE Concept

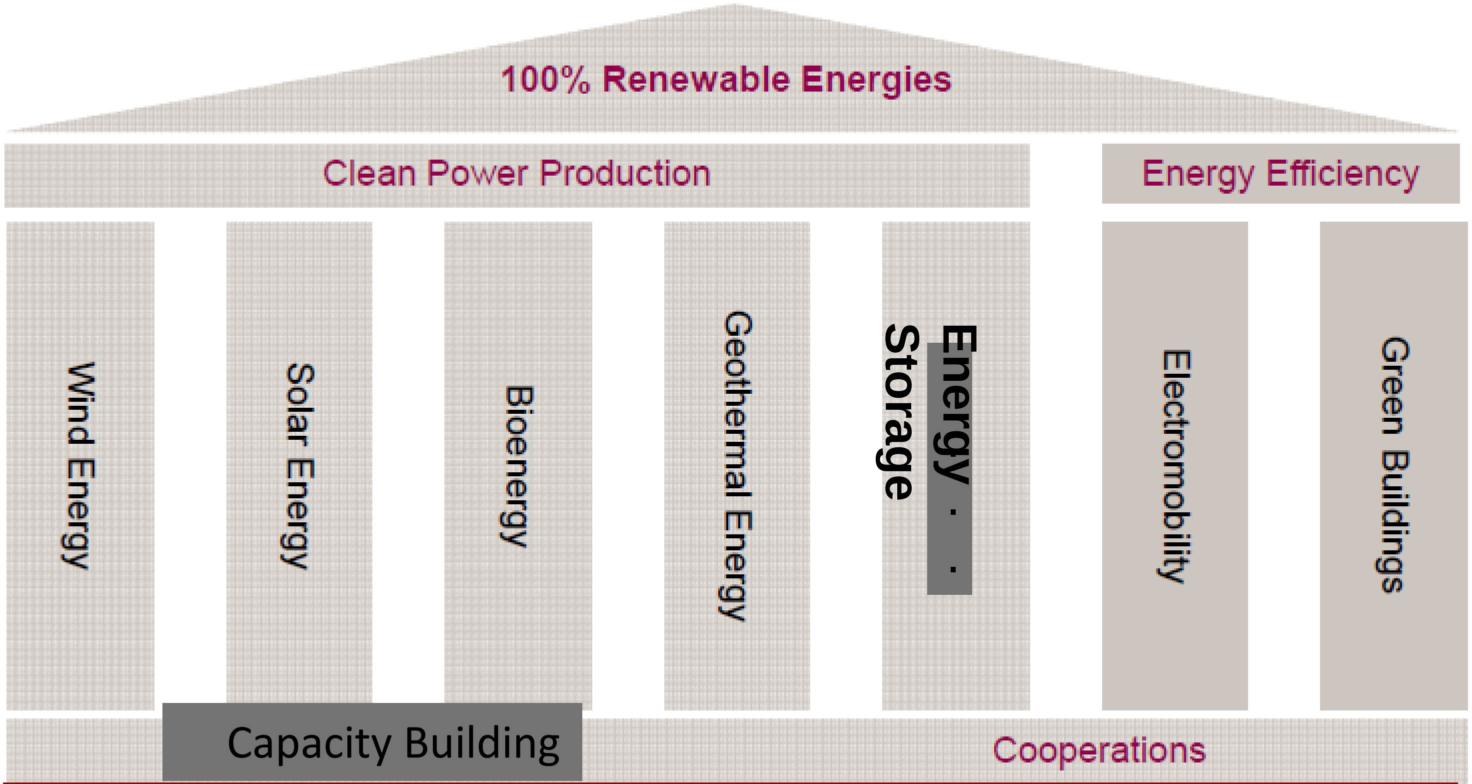
Through the implementation of 100% renewable energy strategy Cape Verde will reduce the reliance on imported food.

Cabo Verde will be able to offer cost efficient harbor and terminal services creating an additional attraction for international investment in logistics and storage facilities

- Due to the nature of renewable energy technologies Cabo Verde will need to generate surplus energy ranging from 241GWh (Scenario of Synthetic Methane Storage) up to 553GWh (Scenario of Pumped Hydro Storage) ⇨ Much more than needed for the coverage of the energy demand in 2020.
- This tremendous overcapacity of cheap electrical work offers a unique opportunity for other, much needed developments on the Cabo Verde islands. Energy can be turned into:
  - some 140 million cubic meter of cheap desalinated water re-vitalizing local agricultural structure,
  - or 2.2 billion passenger kilometer of electric mobility,
  - or into 1,4 million bottles of cooking gas.
- Converting additional electricity into water and agriculture, into methane and fuel for cars or into international competitive cold storage service gives Cabo Verde a unique chance for sustainable economic and industrial development.

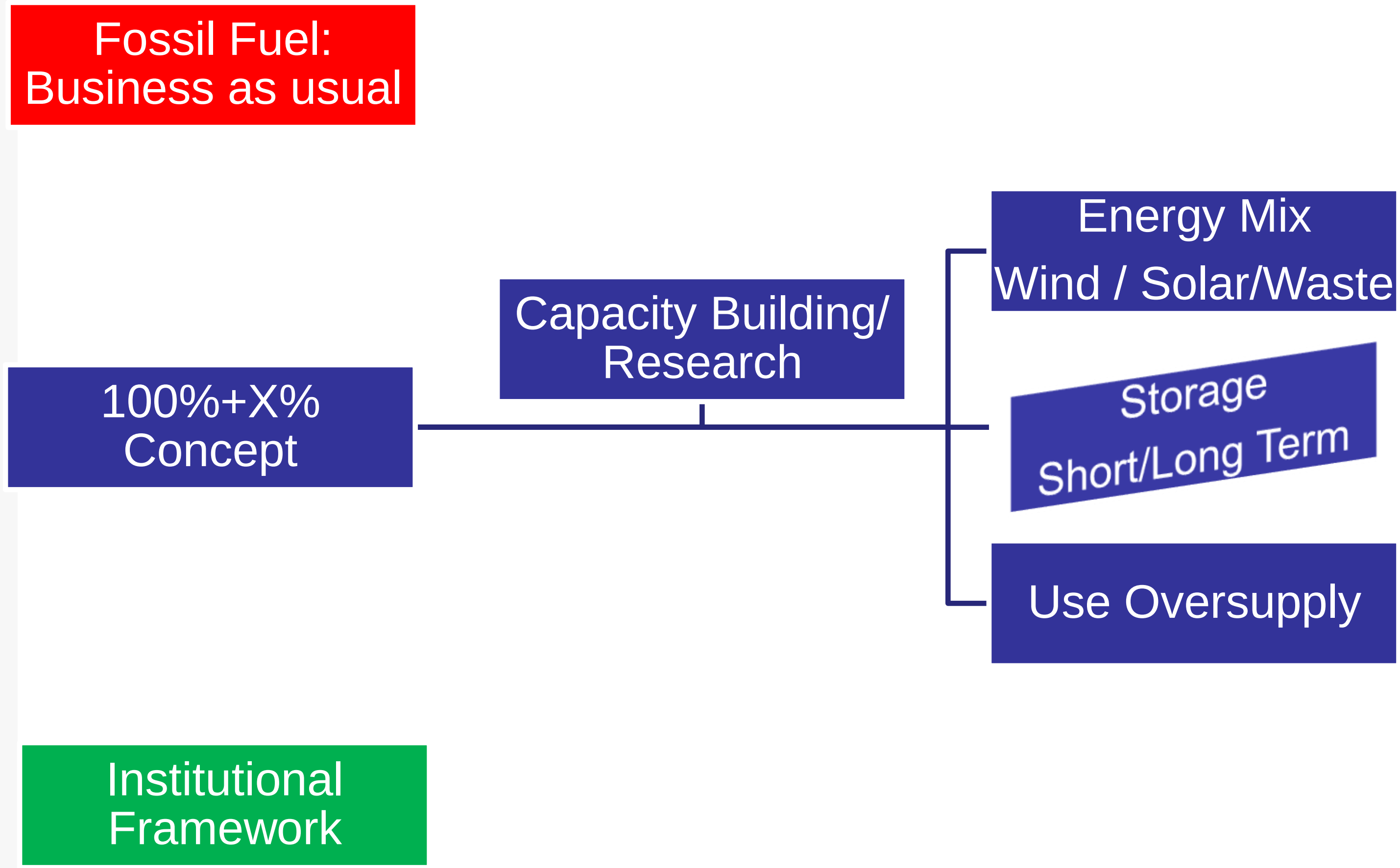
100% + X% Concept: the VISION

VISIONARY, AMBITIOUS but FEASIBLE



Saving 100 % on imported fuel, Building an high efficiency agriculture,
Building a modern cooling logistics for fishery and vegetables,
Building a modern engineering and training society based on Renewable Energy,
Exporting Know-how to other African State and
Building a green tourism economy

Storage: Short and Long Term



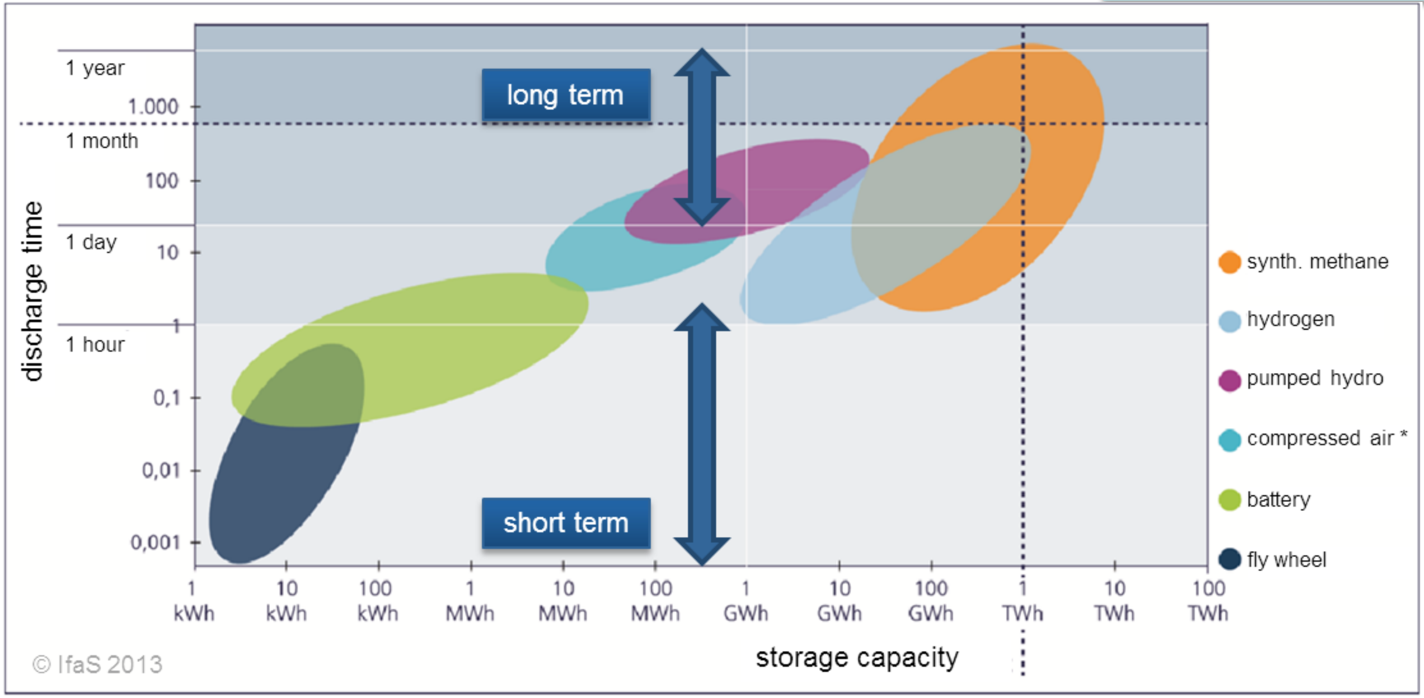
Storage Systems

Need for Storage Systems
Supply from Fluctuating Resources

* Although often stated, compressed air is not a renewable option, since it requires fossil fuel to run a gas turbine as integral part.

Long term
fluctuations, induced by seasonal variations of solar irradiation and appearance of wind

Short term
fluctuations, induced by single events not to be addressed by weather reports like single clouds or turbulences resulting from single gusts



Short Term Storage

Battery Farm in Substation

Different battery technologies (sodium sulfur, NaS; lithium ions Li and vanadium redox Va) show distinct properties in terms of energy-density and power to energy ratio. Lithium based technologies prove their performance for 10,000 cycles. Suppliers already warrant for life cycles of 20 years. Sodium sulfur type batteries are in use for more than a decade

- Large battery systems covering some megawatts of power and some megawatt-hours of storage capacity are foreseen to balance short term fluctuations and provide some reserve energy before backup from seasonal storage has to be considered.

- An energy management system made by an electrical grid that uses information and communications technology to gather and act on information, such as information about the behaviors of suppliers and consumers, in an automated fashion to improve the efficiency, reliability, economics, and sustainability of the production and distribution of electricity

- A sophisticated inverter technology and control software, will respond automatically to changes in grid frequency in millisecond range – faster than any rotating mass, which introduces inertia, only.

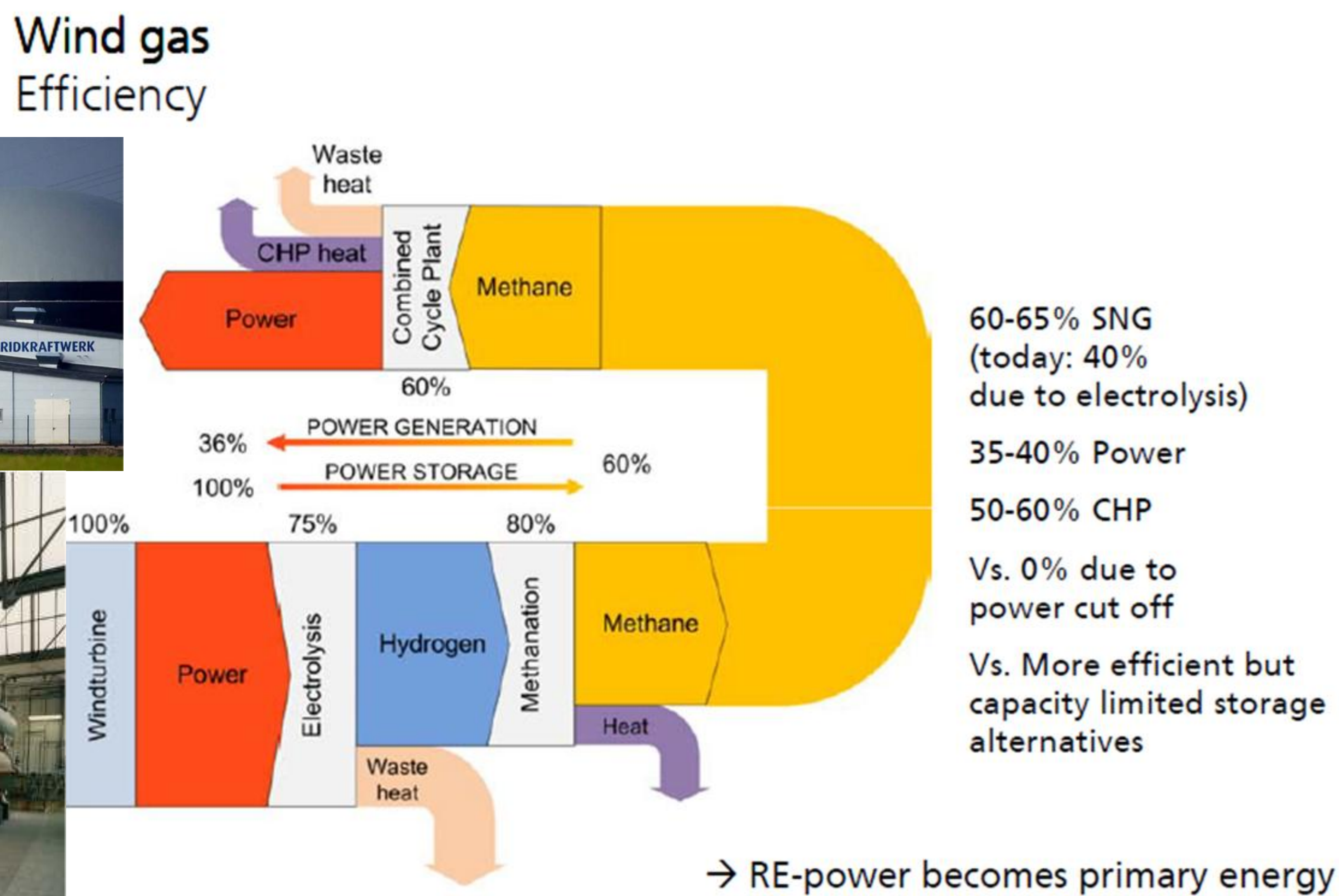
Battery and energy management system to ensure a stable operation of the grid without the need of a running diesel generator

Long Term Storage

Pumped hydro storage

Sterner, 2009 Fraunhofer

Production and Use of Synthetic Methane



Sturner 2009 Fraunhofer

Hydrolyzer (3.5 MW)

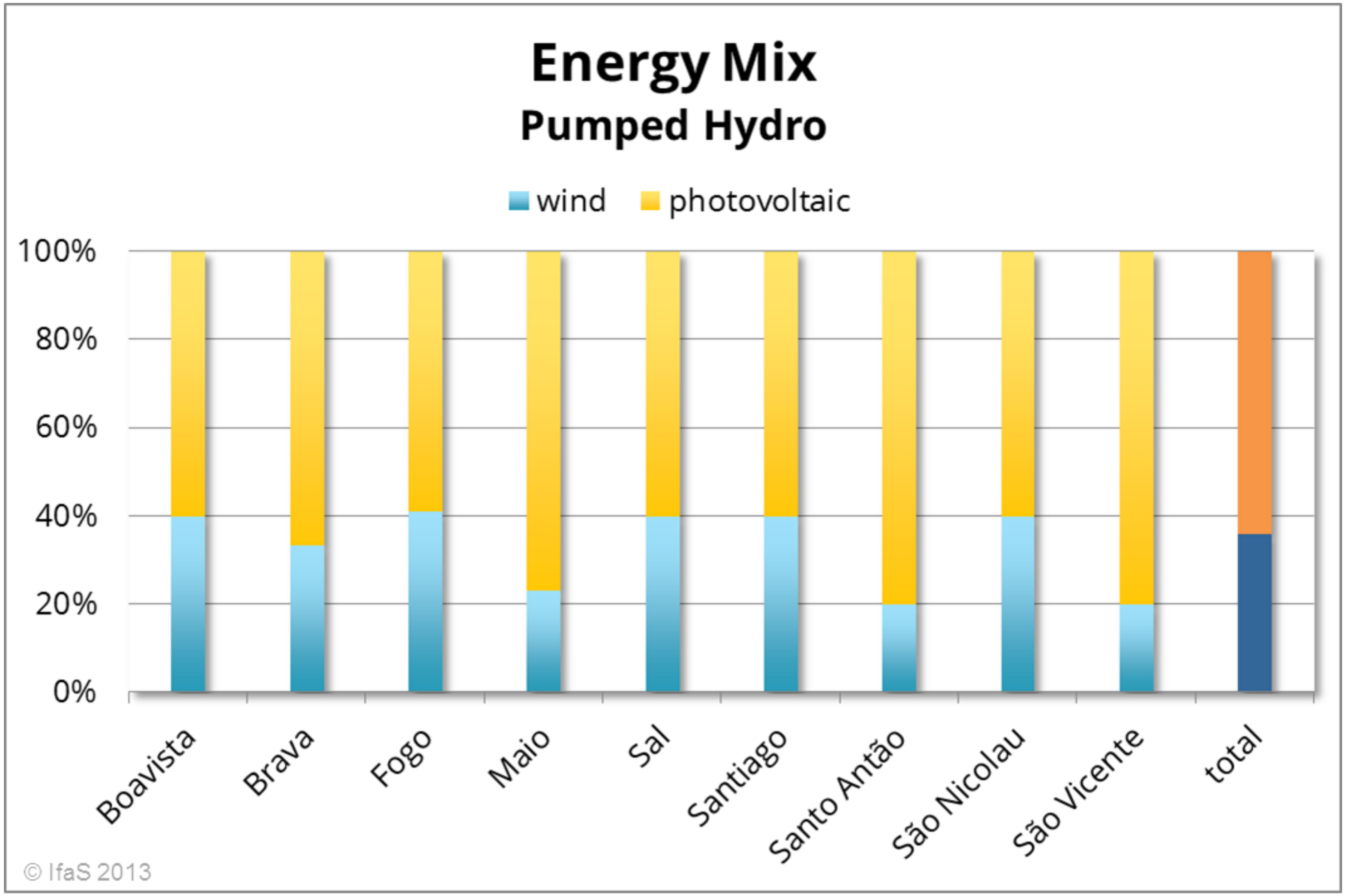
Pumped Hydro: Energy Mix

seasonal storage

- pumped hydro

assumptions

- storage power
  ≥ peak demand
- storage capacity
  > 1 day reserve
- battery power
  50 % peak demand
- installed power
  least installed power
  to meet given
  storage reserve



Pumped Hydro: Investment by Island

seasonal storage
- pumped hydro
- operating cycle: 40 yrs

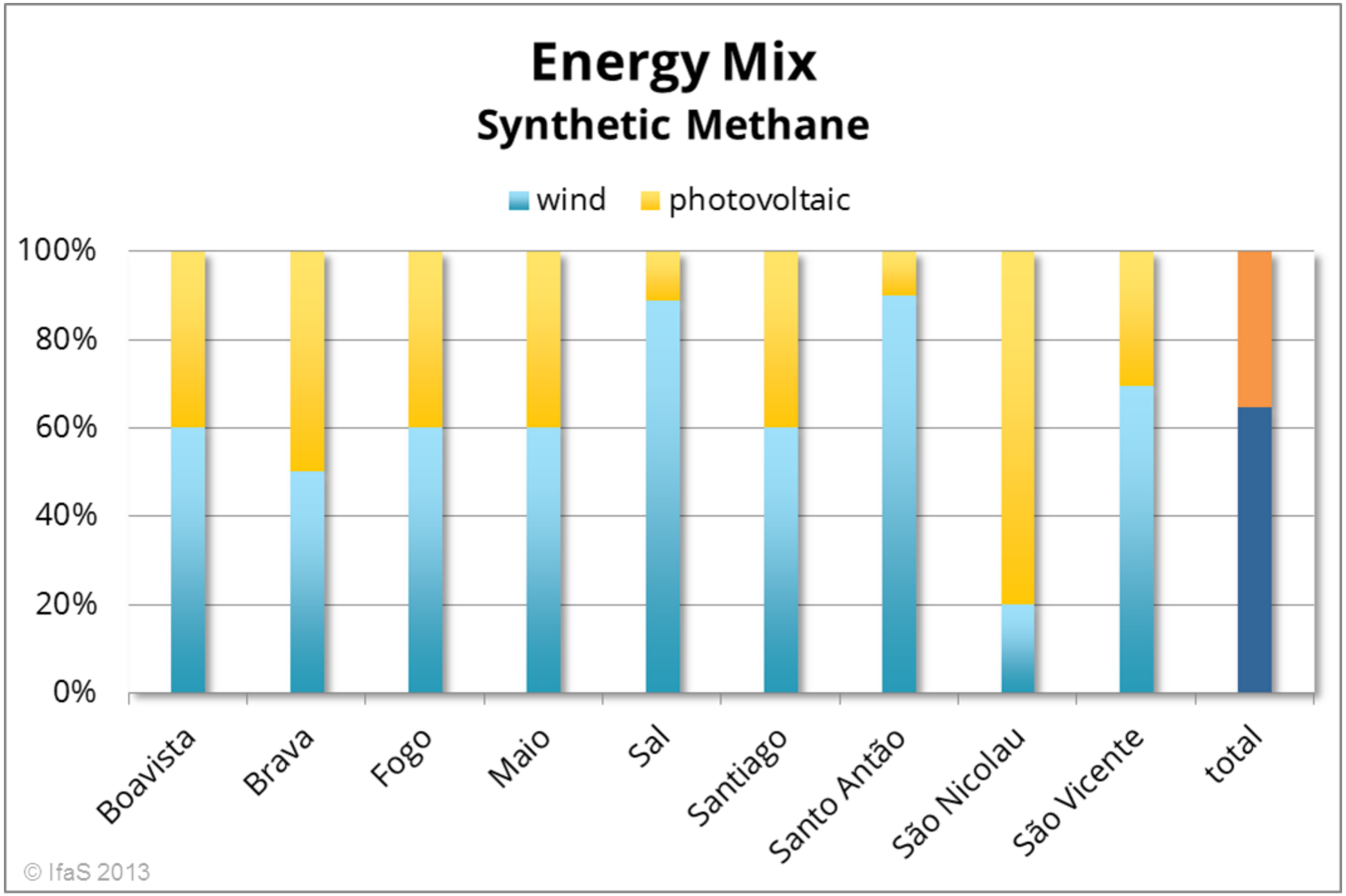
assumptions
- storage power ≥ peak demand
- storage capacity > 1 day reserve
- battery power 50 % peak demand
- installed power least installed power to meet given storage reserve

investment	power generation and storage infrastructure				
	photovoltaic	wind	battery	seasonal storage	total per island
Boavista	50,4 Mio. €	47,6 Mio. €	16,2 Mio. €	50,0 Mio. €	**164 Mio. €**
Brava	2,9 Mio. €	1,0 Mio. €	1,8 Mio. €	2,0 Mio. €	**8 Mio. €**
Fogo	12,2 Mio. €	11,6 Mio. €	3,6 Mio. €	15,0 Mio. €	**42 Mio. €**
Maio	12,5 Mio. €	4,4 Mio. €	1,8 Mio. €	8,6 Mio. €	**27 Mio. €**
Sal	43,2 Mio. €	40,8 Mio. €	16,2 Mio. €	62,0 Mio. €	**162 Mio. €**
Santiago	201,6 Mio. €	190,4 Mio. €	54,0 Mio. €	214,0 Mio. €	**660 Mio. €**
Santo Antão	14,4 Mio. €	5,1 Mio. €	5,4 Mio. €	11,0 Mio. €	**36 Mio. €**
São Nicolau	3,6 Mio. €	3,4 Mio. €	1,8 Mio. €	3,4 Mio. €	**12 Mio. €**
São Vicente	76,8 Mio. €	27,2 Mio. €	18,0 Mio. €	38,0 Mio. €	**160 Mio. €**
total	**418 Mio. €**	**332 Mio. €**	**119 Mio. €**	**404 Mio. €**	**1.272 Mio. €**

Synthetic Methane: Energy Mix

seasonal storage
- synth. methane

assumptions
- storage power
  ≥ peak demand
- storage capacity
  > 1 day reserve
- battery power
  50 % peak demand
- installed power
  least installed power to meet given storage reserve



Synthetic Methane: Investment per Island

seasonal storage
- synth. Methane
- operating cycle: 20 yrs

assumptions
- storage power
  ≥ peak demand
- storage capacity
  > 1 day reserve
- battery power
  50 % peak demand
- installed power
  least installed power to meet given storage reserve

investment	power generation and storage infrastructure				
	photovoltaic	wind	battery	seasonal storage	total per island
Boavista	28,8 Mio. €	61,2 Mio. €	16,2 Mio. €	42,4 Mio. €	**149 Mio. €**
Brava	1,5 Mio. €	2,1 Mio. €	1,8 Mio. €	2,5 Mio. €	**8 Mio. €**
Fogo	7,2 Mio. €	15,3 Mio. €	3,6 Mio. €	9,7 Mio. €	**36 Mio. €**
Maio	4,8 Mio. €	10,2 Mio. €	1,8 Mio. €	7,7 Mio. €	**25 Mio. €**
Sal	4,2 Mio. €	53,6 Mio. €	16,2 Mio. €	51,1 Mio. €	**125 Mio. €**
Santiago	72,0 Mio. €	153,0 Mio. €	54,0 Mio. €	172,0 Mio. €	**451 Mio. €**
Santo Antão	1,2 Mio. €	15,3 Mio. €	5,4 Mio. €	13,4 Mio. €	**35 Mio. €**
São Nicolau	1,1 Mio. €	6,1 Mio. €	1,8 Mio. €	4,2 Mio. €	**13 Mio. €**
São Vicente	16,2 Mio. €	53,6 Mio. €	18,0 Mio. €	60,0 Mio. €	**148 Mio. €**
total	**137 Mio. €**	**370 Mio. €**	**119 Mio. €**	**363 Mio. €**	**989 Mio. €**

Power generation and storage infrastructure

A combination of battery and new inverter were defined as short term storage facility as the combination of both are delivering vital grid stability function and are commercially available.

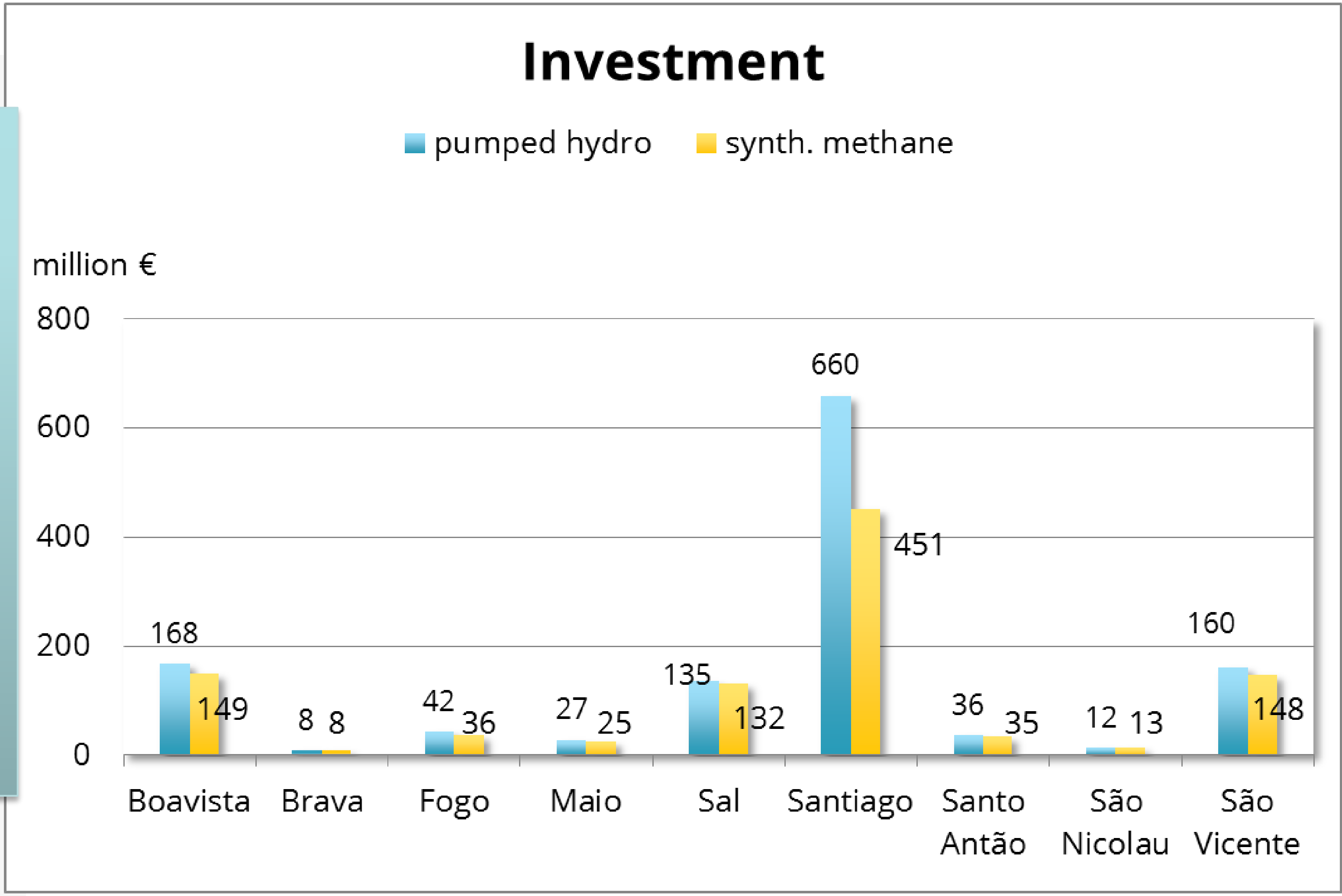
For seasonal storage (up to 7 days of full load) the two technical options of pumped hydro storage (PHS) and power-to-gas were evaluated. While PHS is a mature technology (but requiring certain topographical conditions) the power-to-gas technology is currently undergoing the commercialisation (in particular in Germany) and yet has to prove its applicability on the magnitude foreseen on Cape Verde.

Necessary renewable energy capacities to be installed [including short-term storages (vital for grid stability) and seasonal storages]

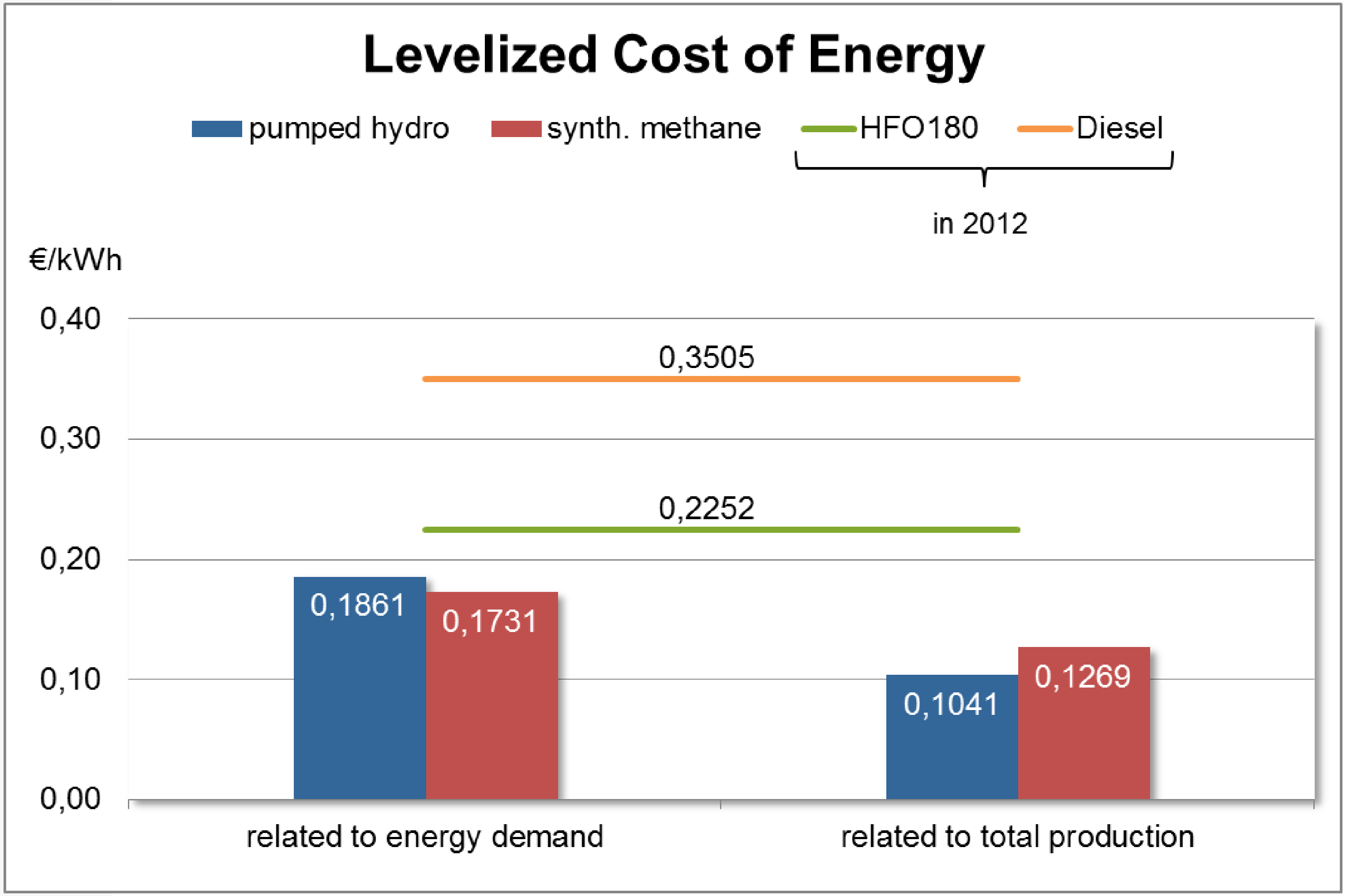
installed power	power generation and storage infrastructure			
	photovoltaic	wind	battery	seasonal storage
Boavista	35 MW	35 MW	9 MW	1.600 MWh
Brava	2 MW	1 MW	1 MW	70 MWh
Fogo	10 MW	7 MW	2 MW	550 MWh
Maio	10 MW	3 MW	1 MW	280 MWh
Sal	39 MW	17 MW	9 MW	1.200 MWh
Santiago	168 MW	112 MW	30 MW	7.700 MWh
Santo Antão	12 MW	3 MW	3 MW	250 MWh
São Nicolau	3 MW	2 MW	1 MW	110 MWh
São Vicente	64 MW	16 MW	10 MW	900 MWh
total	**343 MW**	**196 MW**	**66 MW**	**12.660 MWh**

Total Investment per Island

total investment
- **pumped hydro ca. 1.3 billion €**
- **synth. methane 1 billion €**

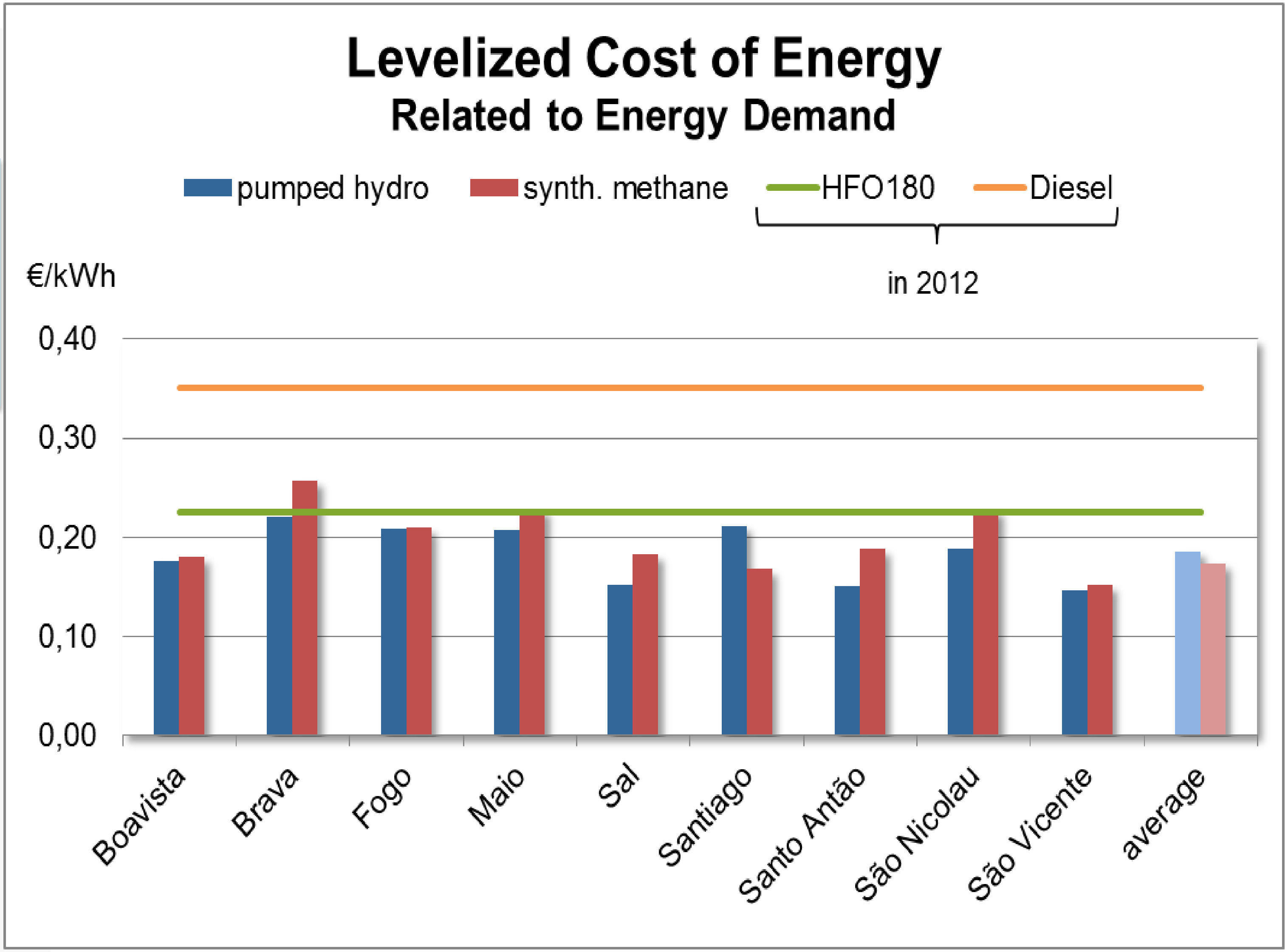


Levelized Cost of Energy: Average for all Islands



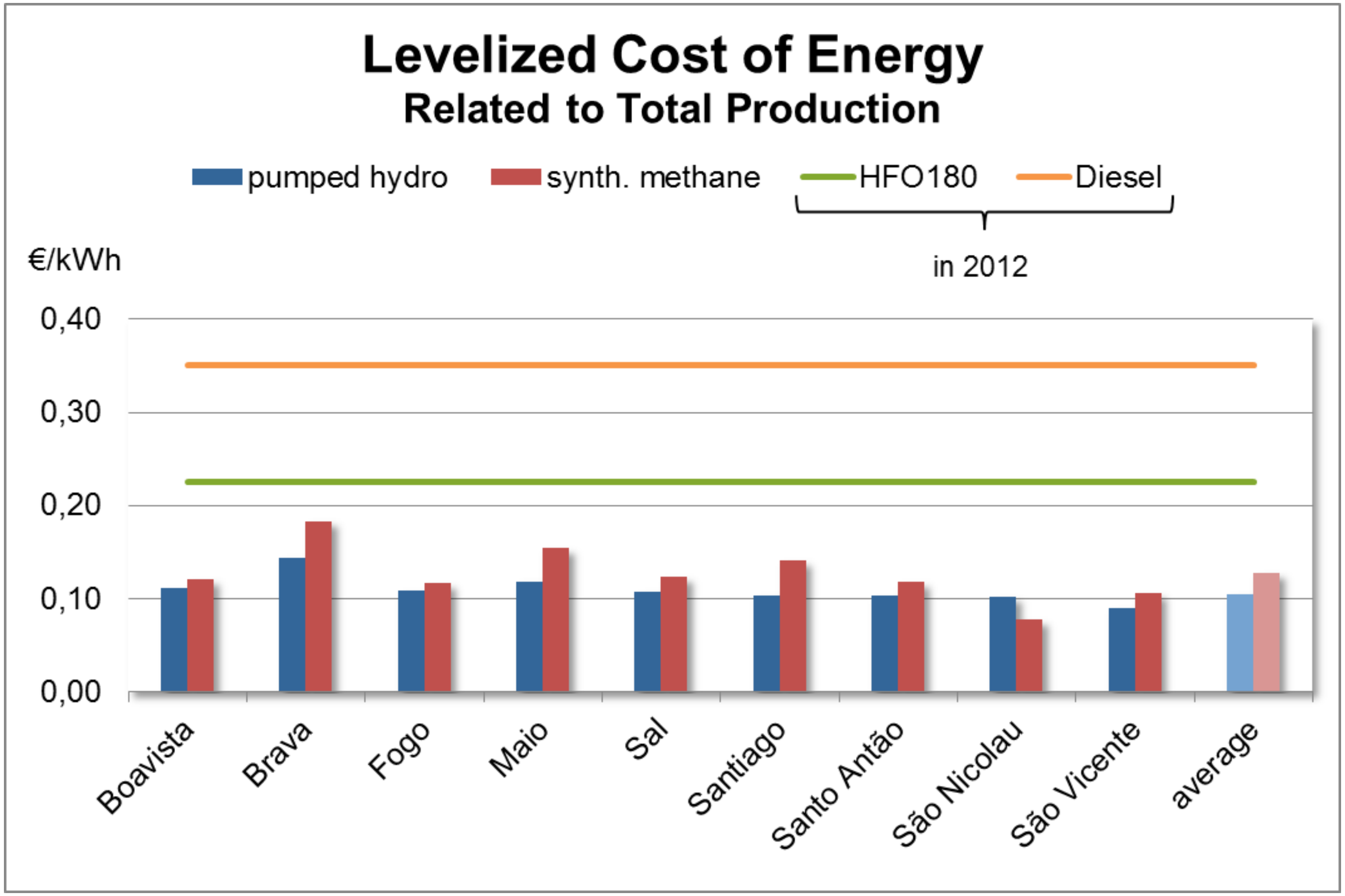
LCOE – Related to Energy Demand

assumptions
- demand according to Gesto Study, “business as usual” scenario for 2020



LCOE – Related to Total Energy Production

assumptions
- production according to energy mix, assuming flexible additional demand

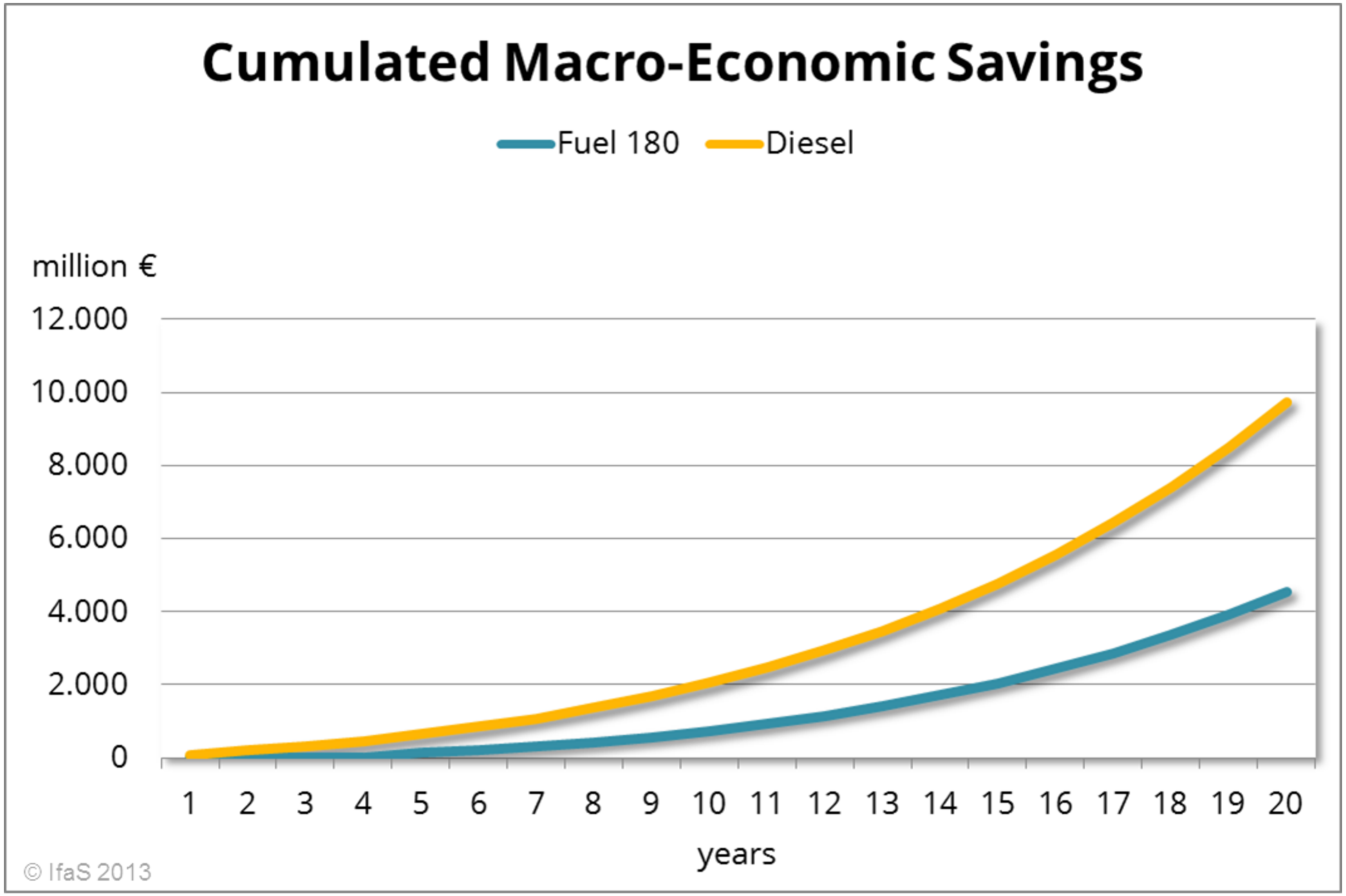


Macro-Economic Effect

Keeping current trends

assumptions
- demand
  demand of 2020 (constant)
- fuel cost
  starting with fuel cost of 2012

- HFO 180
  cost 0,73 €/kg
  increase 10,3 %/a
  (period 2002-2012)
- Diesel
  cost 0,91 €/l
  increase 10,9 %a
  (period 2002-2012)



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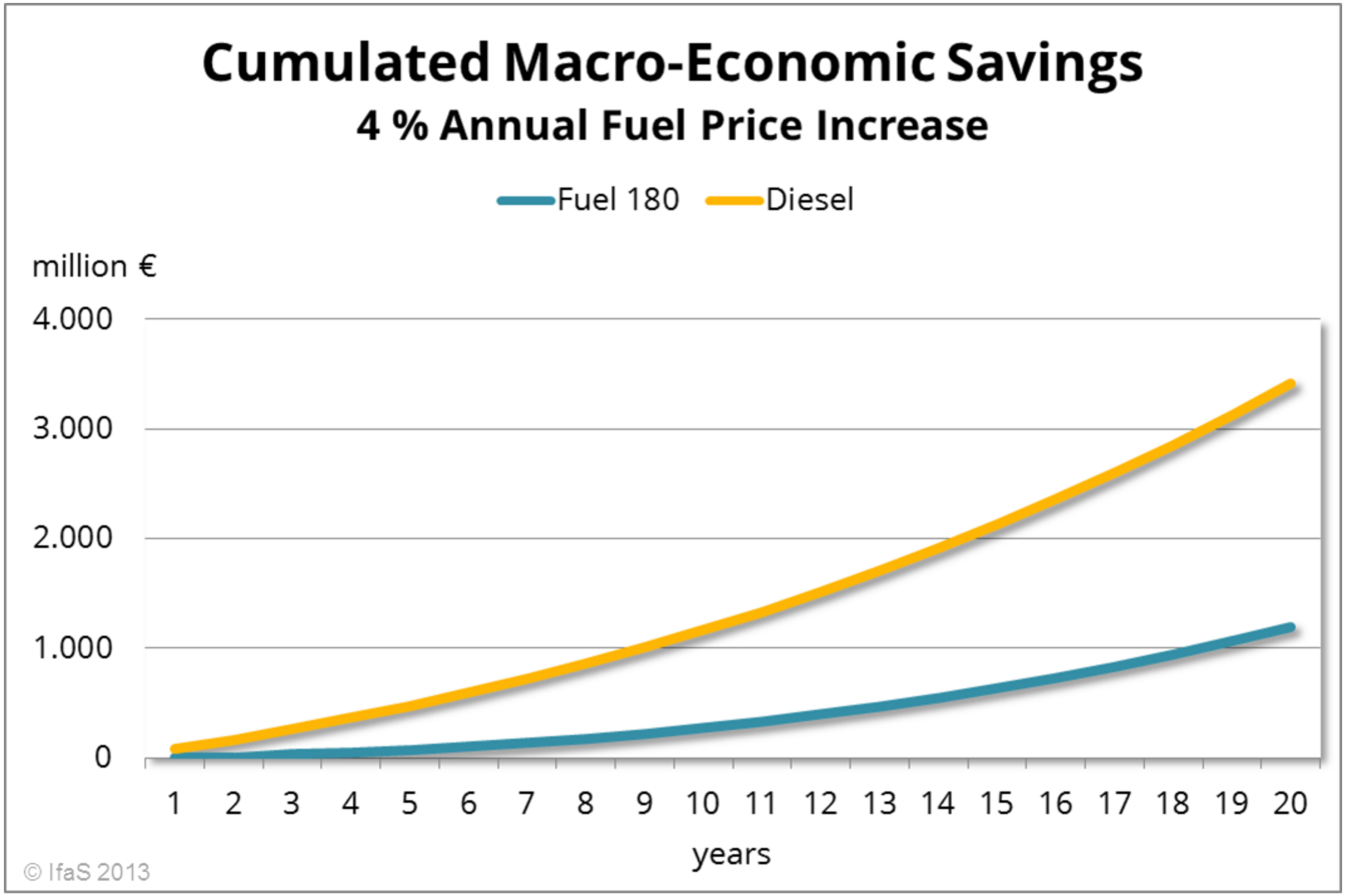


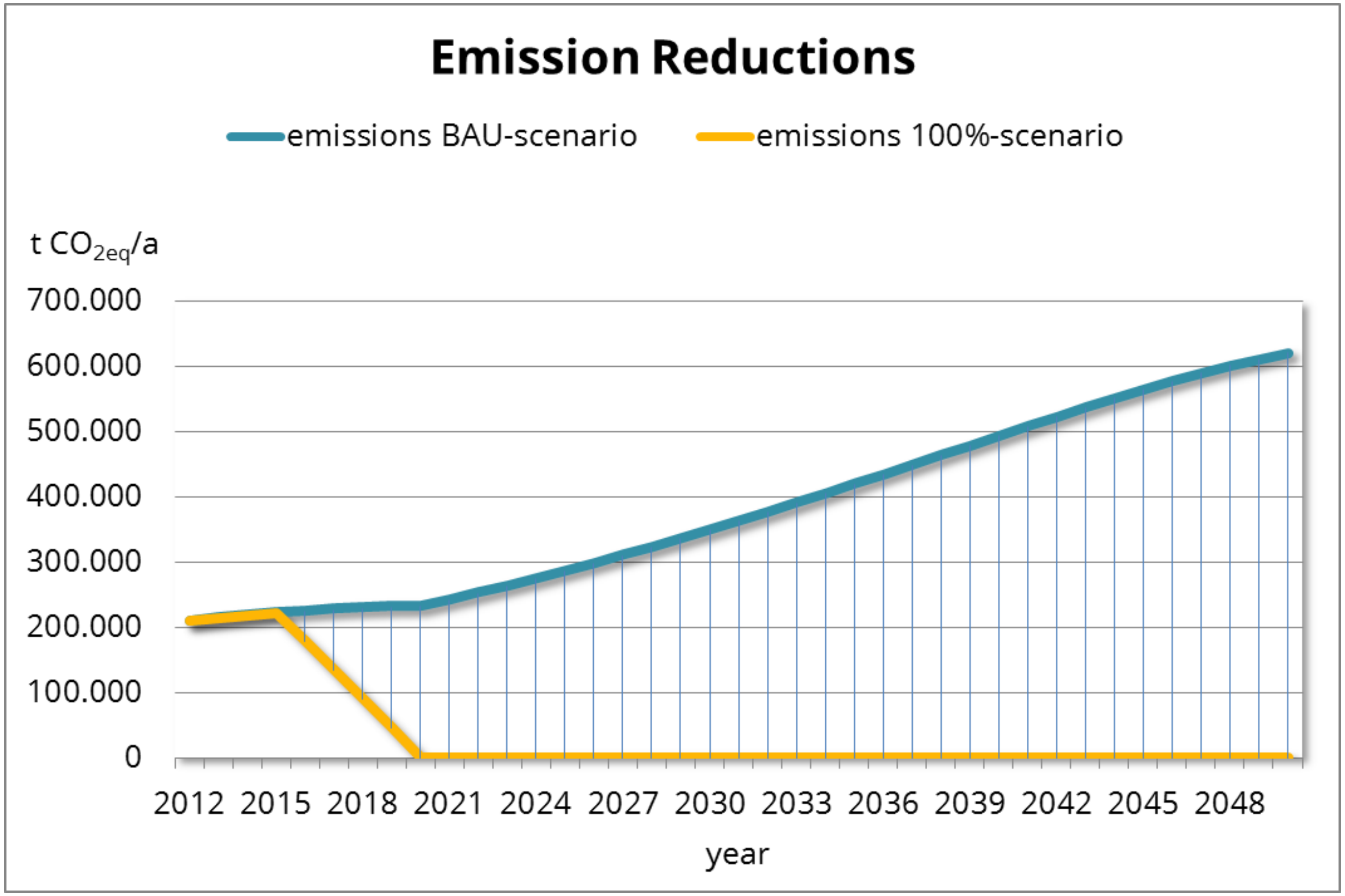
NAMA Potentials by 100% RE

- 100% RE electricity supply equals to min. up to 6.0 Mio. tons of CO2e / 21years (Fossil Fuel Switch)
  - Assumption 0,9 kg CO2e/kWh (in 2012) declining to 0.1 CO2e / kWh in 2020
- 100% RE Water Supply (25.000m3/day/21years) equals up to 1.2 Mio. tons CO2e / 21years (Fossil Fuel Switch)
- 100% Waste-to-Energy Recovery equals to min. 1.0 Mio. tons CO2e / 21years (Avoided LFG)

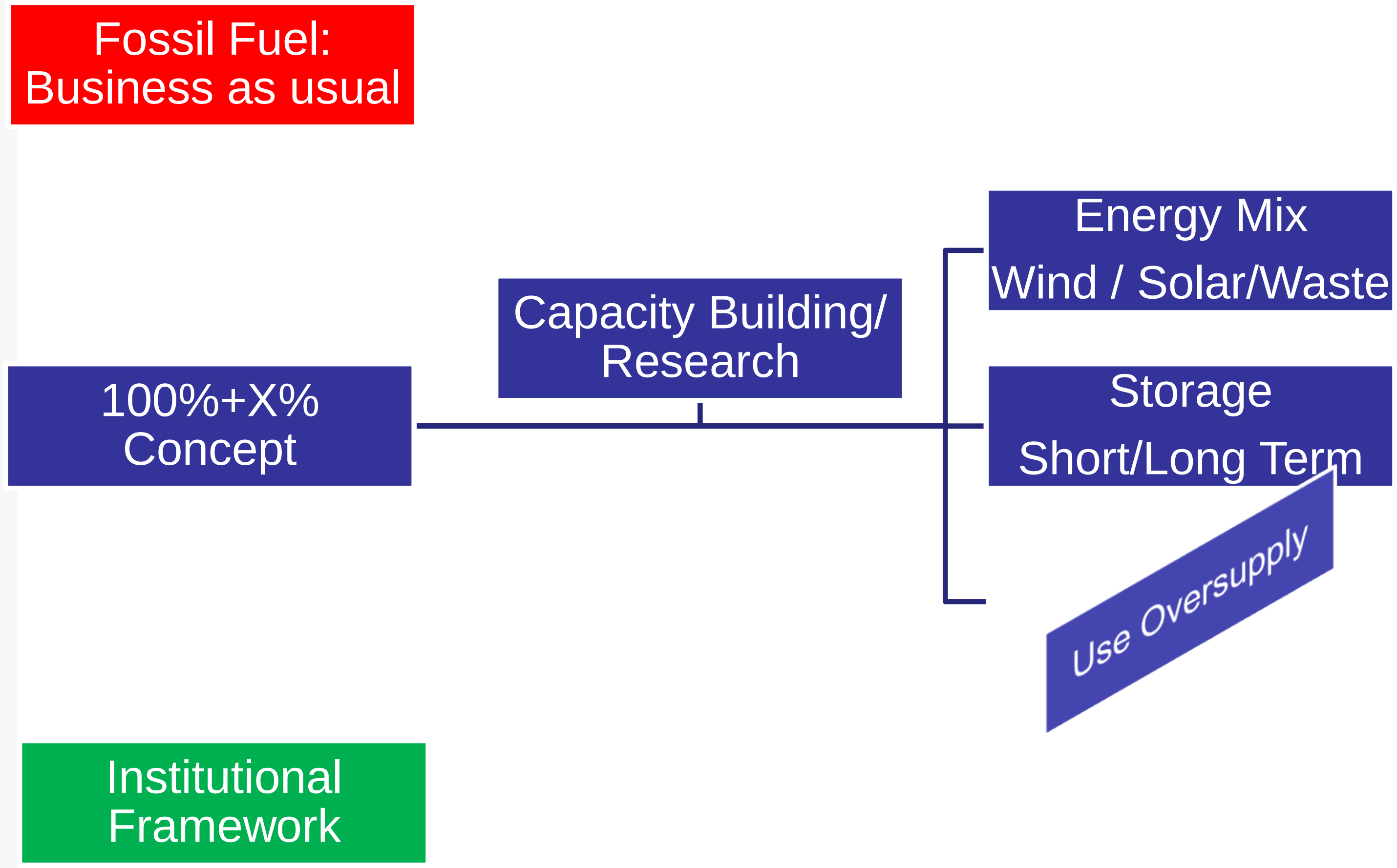
Emission Reductions by 100 Renewable Supply

assumptions

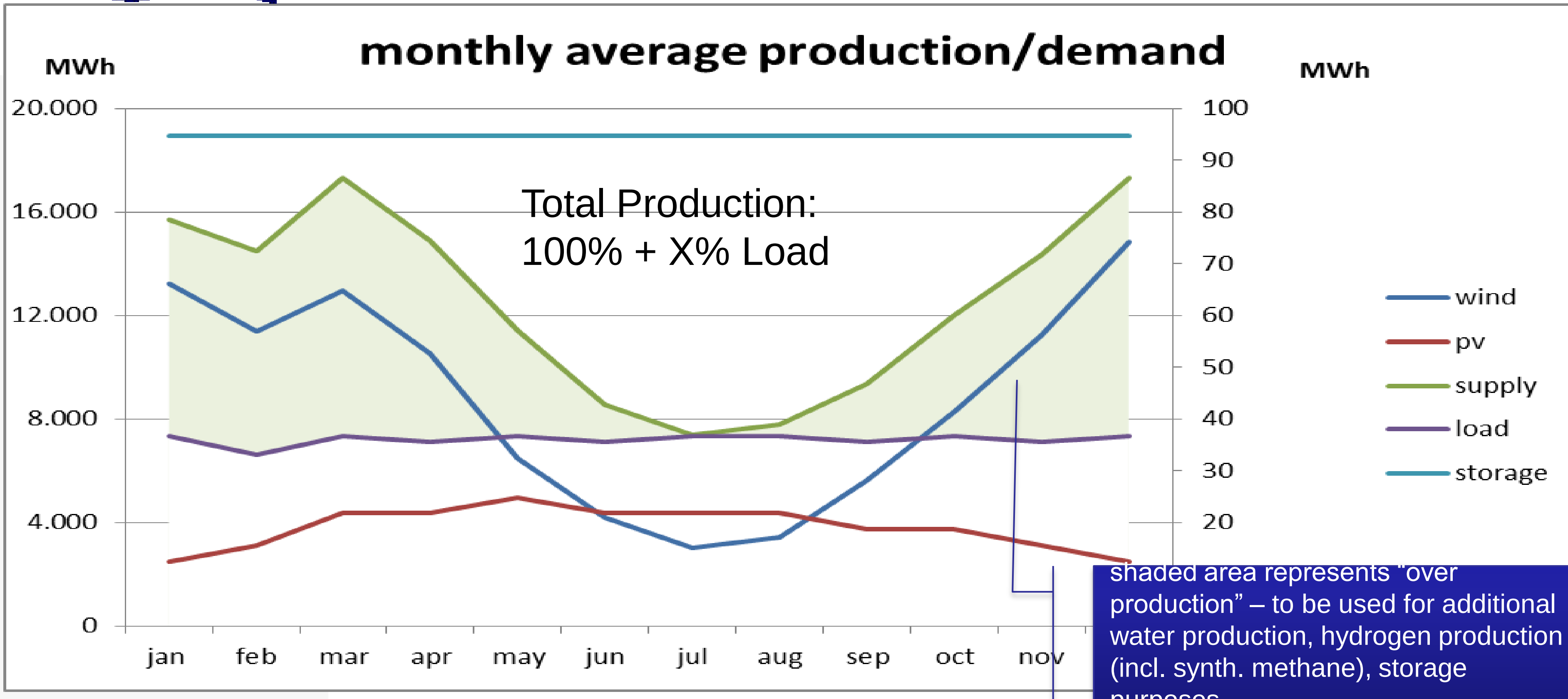
- demand of 2020 from Gesto study, “business-as-usual”-scenario
- estimated figures, only
- further increase of emissions by enhancement of installed power will be reduced by additional shares of renewable supply of up to 80% in 2050



Excess Energy Use



Use of oversupply



Oversupply represents a valuable resource by itself; new businesses with temporal switchable load may be developed. In addition, making use of this resource may lead to different models for electricity market itself:

· temporal switchable loads may be subject to special low tariffs, enabling agricultural cultivation by desalinated sea water (actually energy cost for desalinization are prohibitive for irrigation purposes)

· additional revenues from switchable loads may be used for cross-subsidization and thus lead to lower electricity production cost

· a mixture of these proposals

Excess Energy Use

Creating Synergy

New intelligent RE consumer

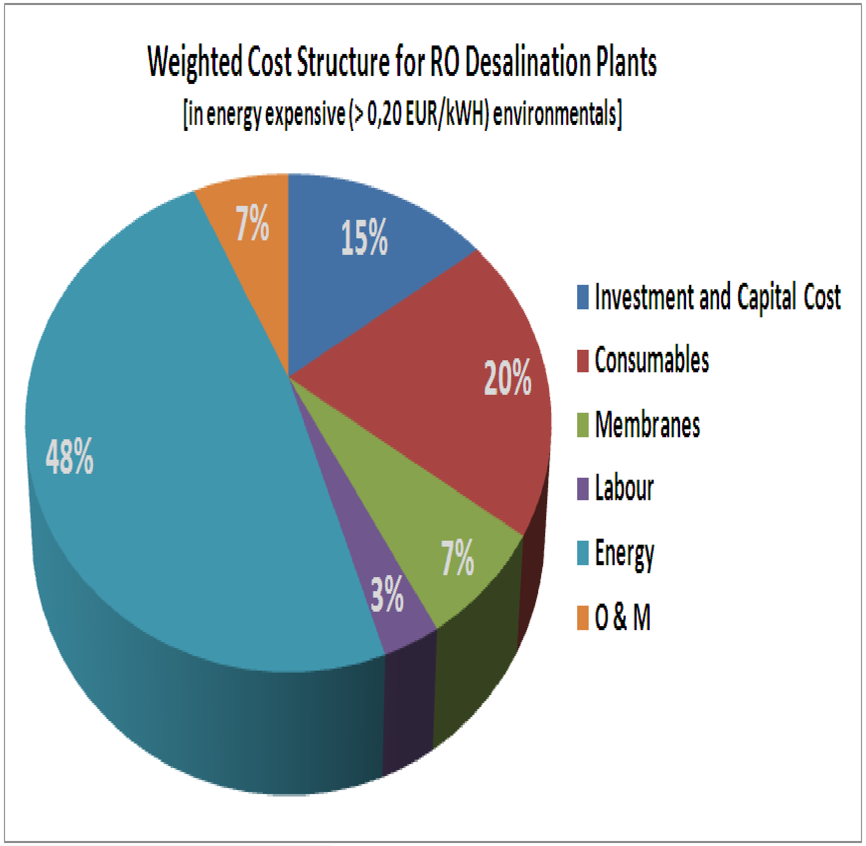
relieving grid instability by stand-by consumption

New employment options

Sharing financial burdens of RE expansion

- Surplus Energy could be utilized as:
  - Water and electricity (Cooling) for an agricultural production
    - 1.000ha of irrigation
      - 100GWh of energy
      - 300.00 Mio Investment
      - 200.000t food production (export) and 5.400 jobs
      - Annual Profit of 38 Mio EUR (at 0,15 EUR/kWh)
  - Lower domestic water and electricity price
  - Production of synthesized methane (36.5 GWh_{therm} can produce 3.650.000m3 of methane)
    - Substitution for cooking gas
    - Substitution of diesel (transportation)
    - Used as diesel substitute in tri-generation processes at tourism facilities for hot water, decentralized electricity and cooling energy
  - Grey water Re-use (Industry, Tourism, Municipality)
  - Brownfield and Greenfield Applications (100% Tourism)
  - Fishing and Fish Processing
    - Cooling for Ice and Refrigeration
    - Thermal for Canning

Excess Energy Use: Cost Structure – RO based Desalination



- Current Freshwater Production Costs per m3 are **around 3,00 EUR**
- Current Average Sales Prices vary between **2,98 EUR to 4,98 EUR per** m3
- Current Energy Costs vary between **1,00 to 1,50 EUR/m3**
- Yield per ha is only about 50% of (European) standard
- Domestic selling prices are above import prices

- **Renewable Energy Costs (for excess energy) of averaged 0,10 EUR/kWh could decrease the water production costs up to 30%**

Transforming Excess Energy in Food

Agriculture is an interesting option to utilise excess energy

The 100+X% strategy will re-vitalize agricultural structures which had been abandoned due to high water prices.

- The underlying 100% renewable energy supply is not only ensuring energy security; it also has the potential to ensure the water and food security, too!
- The tremendous overcapacity of cheap electrical work offers unique opportunities to transform the excess electricity into water via desalination processes (as a kind of secondary storage and dispatchable consumer option) since it will be technically and economically easy to establish a water storage facilities for 15 days of irrigation

Transforming Excess Energy in Food

Investing in RE is an highly lucrative investment option since is:

- creating more investment in agriculture
- Enhancing food security and creating new export options
- maintaining local jobs and creating significantly new employment options
- Creating in the mid-and long term development perspectives, new industrial clusters and agricultural production processes and products

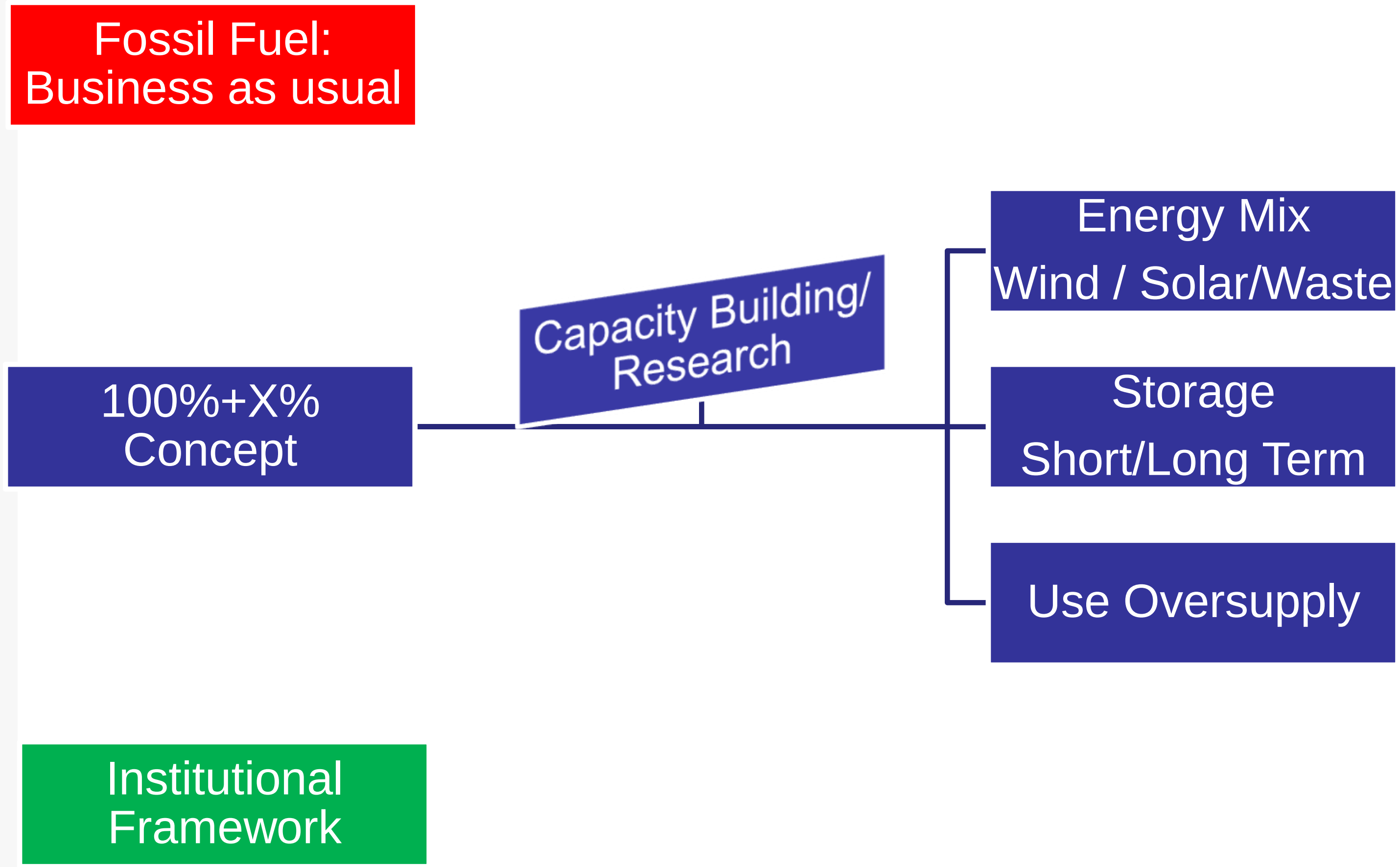
Excess Energy:

Green Agriculture and New Added Value Process

:

- Zero Discharge Seawater Desalination: Integrating the Production of Freshwater, Salt, Magnesium, and Bromine
- Domestic production of fertilizer based on renewable energies.
- **Ecological Agriculture**
  - Storage of excess energy in nitrogen, phosphorous and potassium + trace elements by:
  - Haber-Bosch Synthesis Option (12,5kWh/kgN)
  - Ammonium-Magnesium-Phosphat Precipitation from sewage sludge and waste water
  - Potassium extraction from brine of reverse osmosis (desalination processes)

OUTLINE



Fossil Fuel: Business as usual
100%+X% Concept
Capacity Building/ Research
Energy Mix
Wind / Solar/Waste
Storage
Short/Long Term
Use Oversupply
Institutional Framework

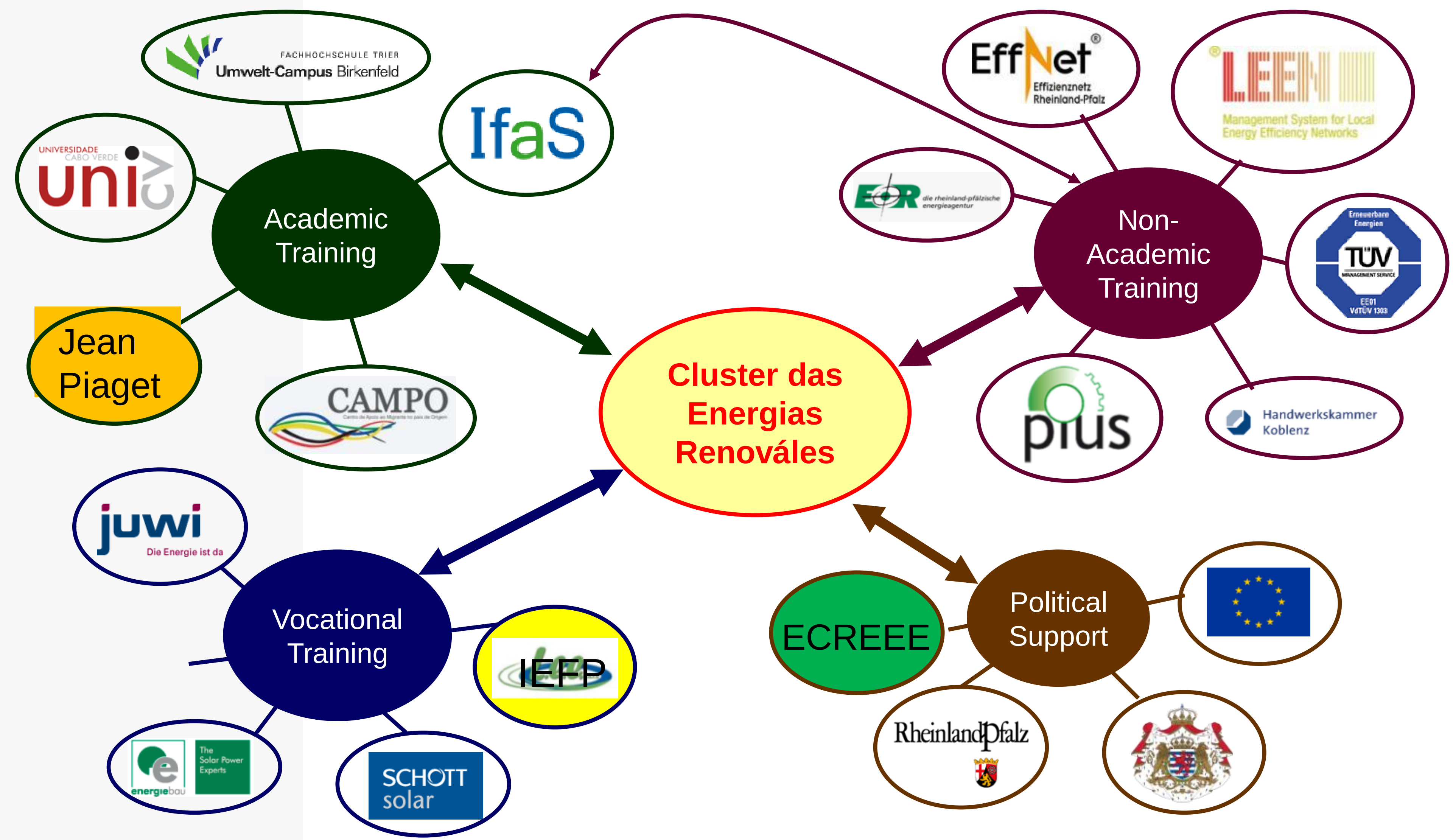
Education for the energy transition

Despite the “hardware” for the implementation of the ambitious energy transition strategy towards 100% renewable energy, it will be crucial for the success to establish an intensive capacity building and knowledge-creation-process, as well as its appropriate structures.

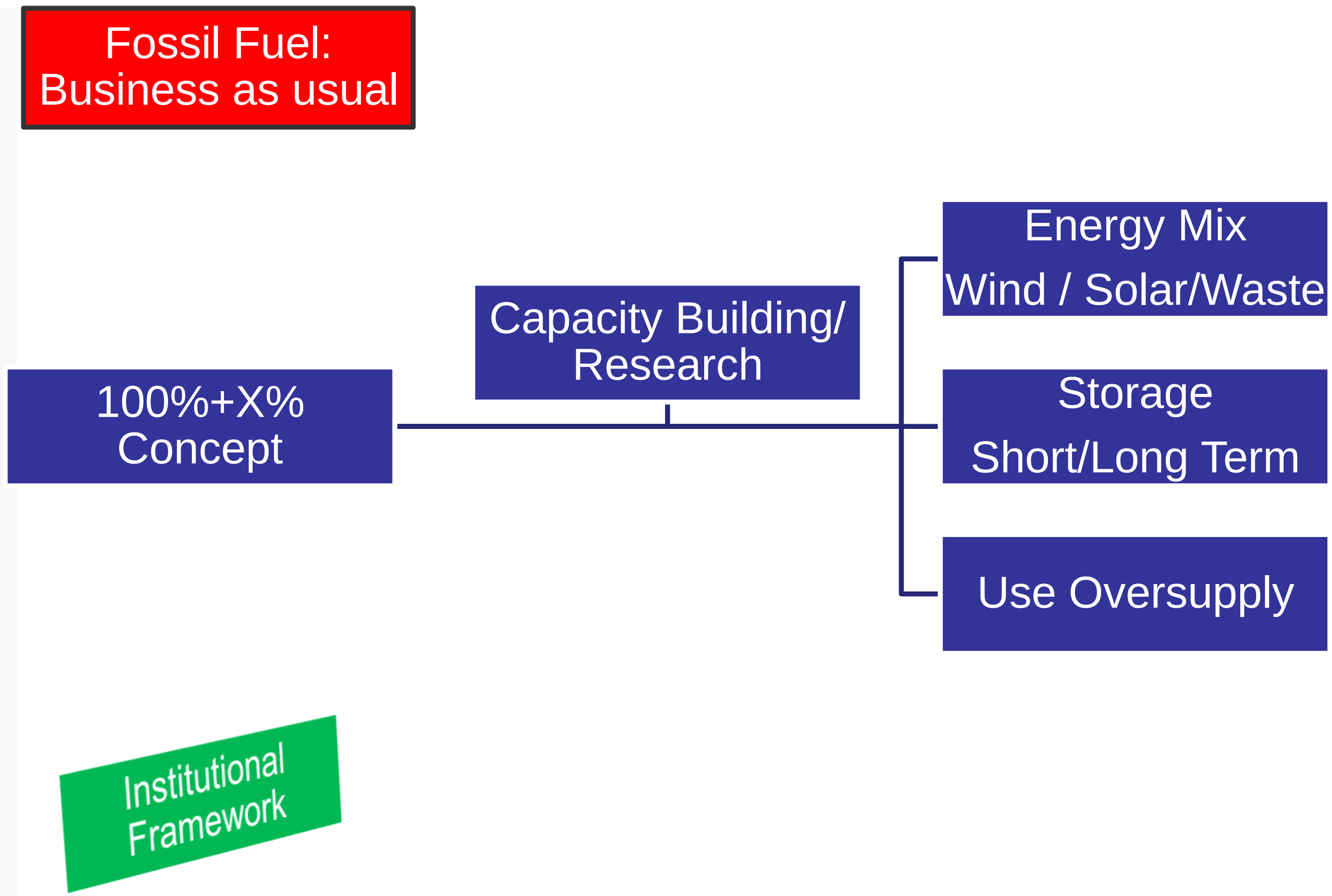
Knowledge and soft skills are necessary:

- On craftsmen level
  - In the initial phase it is necessary to identify and evaluate the existing craftsman educative programs in both, structure and content.
  - In the mid and long term it is suggested that at Cabo Verde the structure of dual practical and theoretical apprenticeship is in close cooperation with the companies and state owned vocational training schools
- On academic level capacity building strategy will be the establishment of a Zero-Emission University network entitled as “Collaborative Tertiary Education and Applied Research Center in 100% Renewables and Zero Emission System Design in the long-term. The Zero-Emission University network will be located at Cape Verde associated to a Cape Verdean University

Education and Research: Network



Institutional Framework



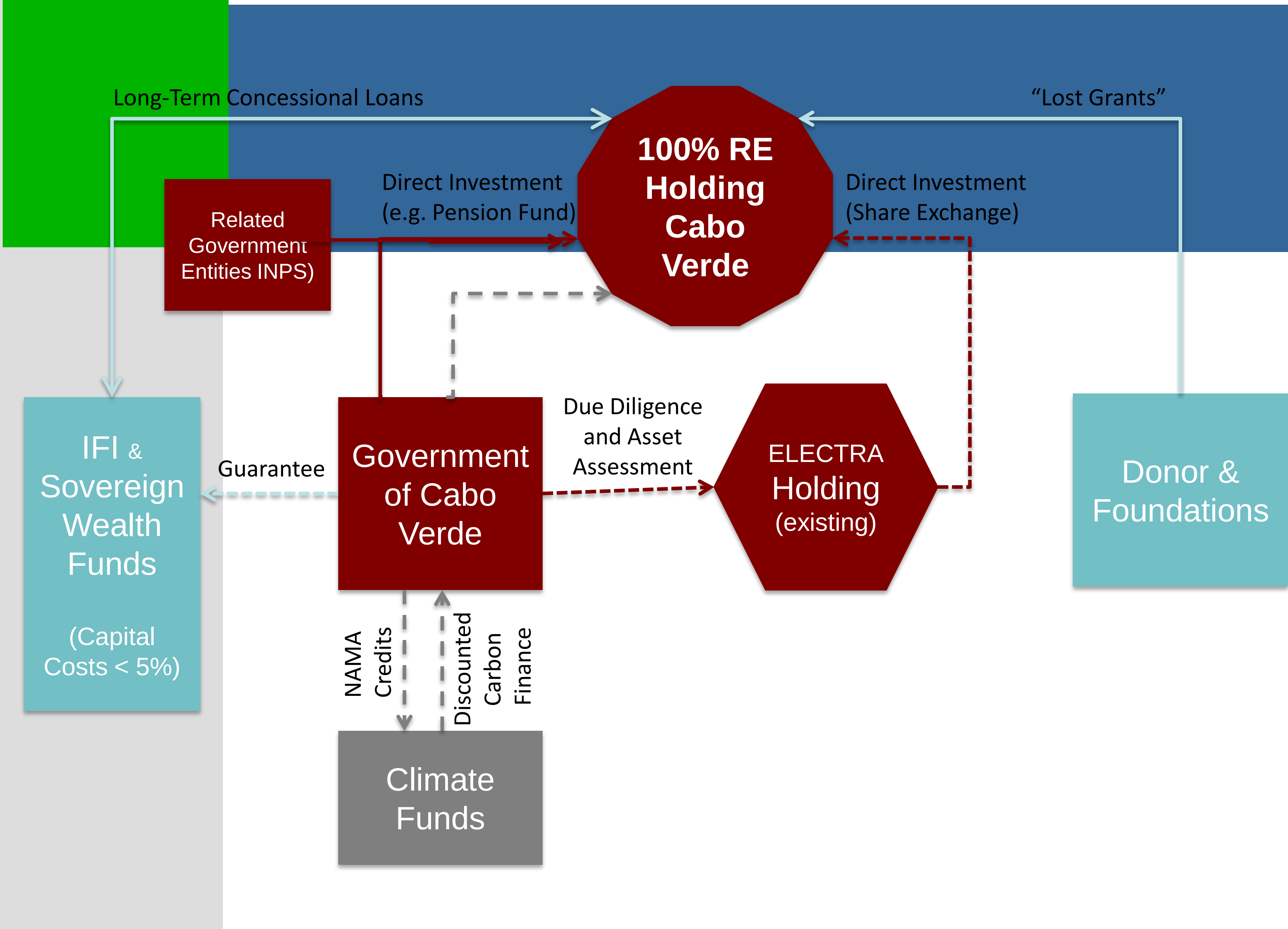
Institutional Framework

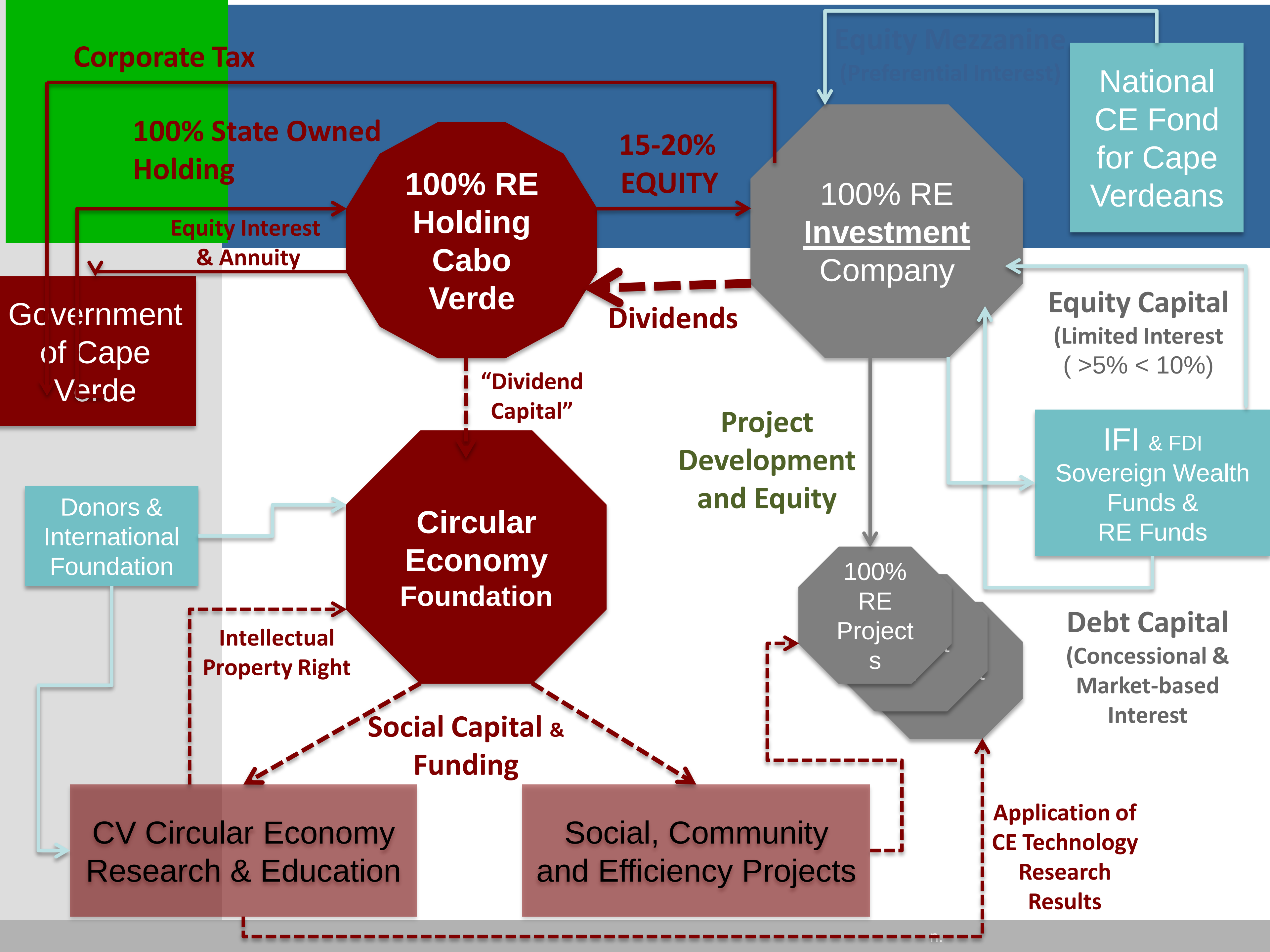
The major obstacle for a quick implementation of the 100% renewable energy master plan lies in the organization of the investment.

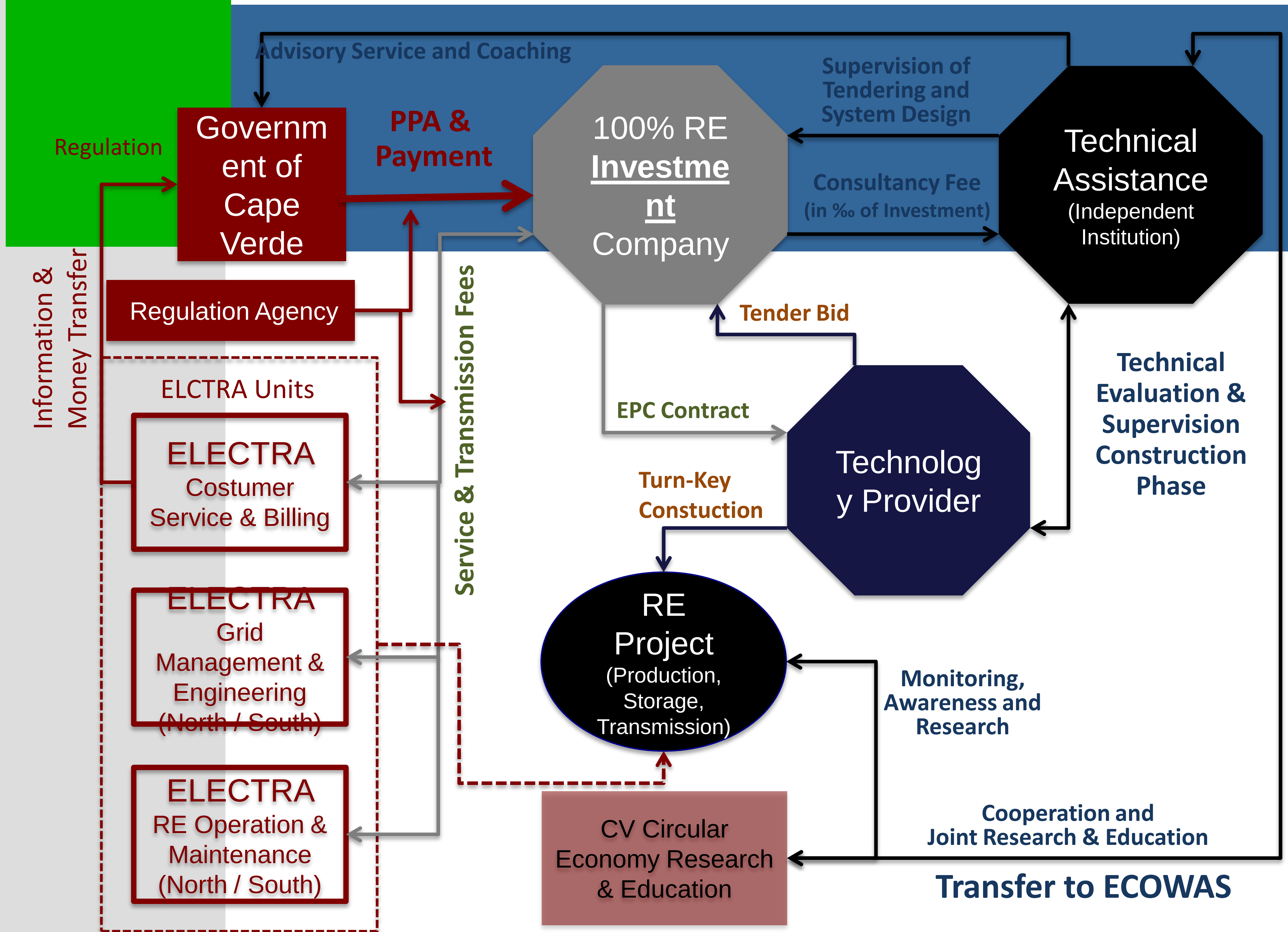
Just exchanging the import of fossil energy by the import of external technology and money will not be the solution to Cabo Verde´s structural problems.

- The master plan proposes a mixture of local and international funding in strong proximity with a change in the organization of the public utility ELECTRA.

- Key concern in the area of money allocation must be the creation and protection of regional and national added value. The first interest should be to create capital values for Cape Verde before offering the investment opportunity to external lenders. And in all cases ownership of the energy system must be in the realm of stakeholders from Cape Verde.


Long-Term Concessional Loans
"Lost Grants"
100% RE Holding Cabo Verde
Related Government Entities INPS)
Direct Investment (e.g. Pension Fund)
Direct Investment (Share Exchange)
IFI & Sovereign Wealth Funds
(Capital Costs < 5%)
Guarantee
Government of Cabo Verde
Due Diligence and Asset Assessment
ELECTRA Holding (existing)
Donor & Foundations
NAMA Credits
Discounted Carbon Finance
Climate Funds


Corporate Tax
100% State Owned Holding
100% RE Holding Cabo Verde
15-20% EQUITY
Equity Mezzanine (Preferential Interest)
National CE Fond for Cape Verdeans
100% RE Investment Company
Equity Interest & Annuity
Government of Cape Verde
Dividends
Equity Capital (Limited Interest (>5% < 10%)
"Dividend Capital"
Project Development and Equity
IFI & FDI Sovereign Wealth Funds & RE Funds
Donors & International Foundation
Circular Economy Foundation
100% RE Project s
Debt Capital (Concessional & Market-based Interest
Intellectual Property Right
Social Capital & Funding
CV Circular Economy Research & Education
Social, Community and Efficiency Projects
Application of CE Technology Research Results



Advisory Service and Coaching
Regulation
Government of Cape Verde
PPA & Payment
100% RE Investment Company
Supervision of Tendering and System Design
Technical Assistance (Independent Institution)
Consultancy Fee (in ‰ of Investment)
Information & Money Transfer
Regulation Agency
Service & Transmission Fees
Tender Bid
ELCTRA Units
ELECTRA Costumer Service & Billing
EPC Contract
Technolog y Provider
Technical Evaluation & Supervision Construction Phase
Turn-Key Constuction
ELECTRA Grid Management & Engineering (North / South)
RE Project (Production, Storage, Transmission)
Monitoring, Awareness and Research
ELECTRA RE Operation & Maintenance (North / South)
CV Circular Economy Research & Education
Cooperation and Joint Research & Education
Transfer to ECOWAS

ROAD MAP to 2020

Short Term Objective until End of 2014: Detail Engineering Concepts and implement first

Mid Term Objective until End of 2017: Installation of new renewable energy production and short-term storages at all islands.

Long Term Objective until End of 2020: Installation of seasonal storages and additional renewable energy production sites

ROAD MAP to 2020

Short Term

- Objective: create immediate solutions enhancing current renewable energy production (penetration) and grid stability.
- Detailed engineering studies for new renewable energy production sites and their grid integration as well short term storage and grid stability measures (battery packs and inverters) will be initiated based on the 100% study (and partly the site pre-evaluations done in the GESTO study). The detail engineering studies - if done cost effectively parallel for all islands and predefined sites – require an initial investment of approximately 10.0 Mio. EURO.

Mid-Term

- On all islands new renewable energy installations as well as short-term storage (up to 12 hours of full load) and grid stability measures are implemented maximising the renewable energy penetration to an economic interesting point possible without seasonal storage concepts.
- In parallel, different seasonal storage (for up to 7 days of full load) technologies are evaluated in detailed engineering studies.

Long Term

- The energy transition towards 100% Renewable shall be completed until 2020 with the construction of seasonal storage technologies based on the expected mature technology and international experiences.
- The detailed engineering concepts are an important pre-requisite for the tendering process and business planning

ROAD MAP to 2020: necessary conditions

- Careful considerations have to be performed for each of the islands. Strategies shall cover the utilization of oversupply by dispatchable loads.
- Implementation phase requires strong governance to follow a systemic approach covering supply and grid related issues jointly.
- Step-by-step implementation has to be developed making use of existing fuel driven generators which can play a vital role as long term (seasonal) storage device in a transition phase while related constructions are on the way. Even as backup they are valuable assets.
- Grid stabilizing by the introduction of battery storages has to be highlighted as one of the first steps for implementation at short term. As a matter of course the design of storage hardware and control shall consider future enhancements to 100 % regenerative supply. Thus renewable production from existing photovoltaic systems and wind turbines may be enhanced to their capabilities without the need for today’s power reductions.

Proposed Project Design for Sal Island

The project aims to develop the technical engineering design as a pre-requisite for a designated tender process for:

1. Wind Park with 7.65-8,5MW nominal power capacity with suitable inverter;
2. PC Park with 2,5MW nominal power capacity with suitable inverter;
3. Battery with 9MW/9MWh and Grid Management System (SCADA System) :

The detailed engineering concept for the positions 1) and 2) include:

- all relevant measurements,
- planning and permitting assessment,
- grid connection design,
- geological survey and environmental impact assessment
- logistics planning.

The detailed engineering concept for position 3) includes:

- Power flow analysis for estimation of grid extension and cross section
- Adoption grid safety concept/selectivity study
- Design concept energy management system/SCADA
- Design of interface to wind park(s) / Design of interface PV plant(s) / Design of control system for existing thermal plant and grid
- Planning/permitting for battery plant
- Infrastructure Specification of the battery inverters
- Preparation of climatisation concept & analysis of fire protection requirements

Requested Funding

The requested funding for the detailed engineering concepts sum up to 1.05 Mio EUR (3% of the designated project value of 35.0 Mio EUR).

ROAD MAP to 2020: Conclusions

- 100 % are by far achievable by existing potentials
- 100 % will cause challenges:
  - grid capacity
  - grid Management
  - storage capacity
  - high investments for power plants, grid, storage and grid management
  - high prices for regulating energy

BUT **100 % are feasible and cost-effective**

OBRIGADO