WORKSHOP ON SOLUTIONS FOR THE ENERGY AND ENVIRONMENTAL SUSTAINABILITY OF PORT AREAS: A PILOT ACTION FOR PORT OF TRIESTE

Study and research to enable cold ironing: approach and discussion

Lab of Grid Connected and Marine Electric Power Generation and Control

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March 9th 2018

Summary

- Cold Ironing
- Starting point (single terminal)
- Design review (route)
- Aim of the study
  - Installation Costs
  - Environmental Costs
  - Running Costs
  - Costs for Ship Owners
- EGREBUTY: Electrical GRid for grEen BUsiness continuiTY
- Conclusions

Emissions at berthing

- Standard berthing (marine bunker fuel) is a very polluting activity

Duration	Fuel Tons	Kg NO_x	Kg SO_2	Kg CO_2	Kg VOC	Kg PM_{10}
1h	2,47	120	130	786	10	20
16h	39,5	1920	2080	12576	160	320

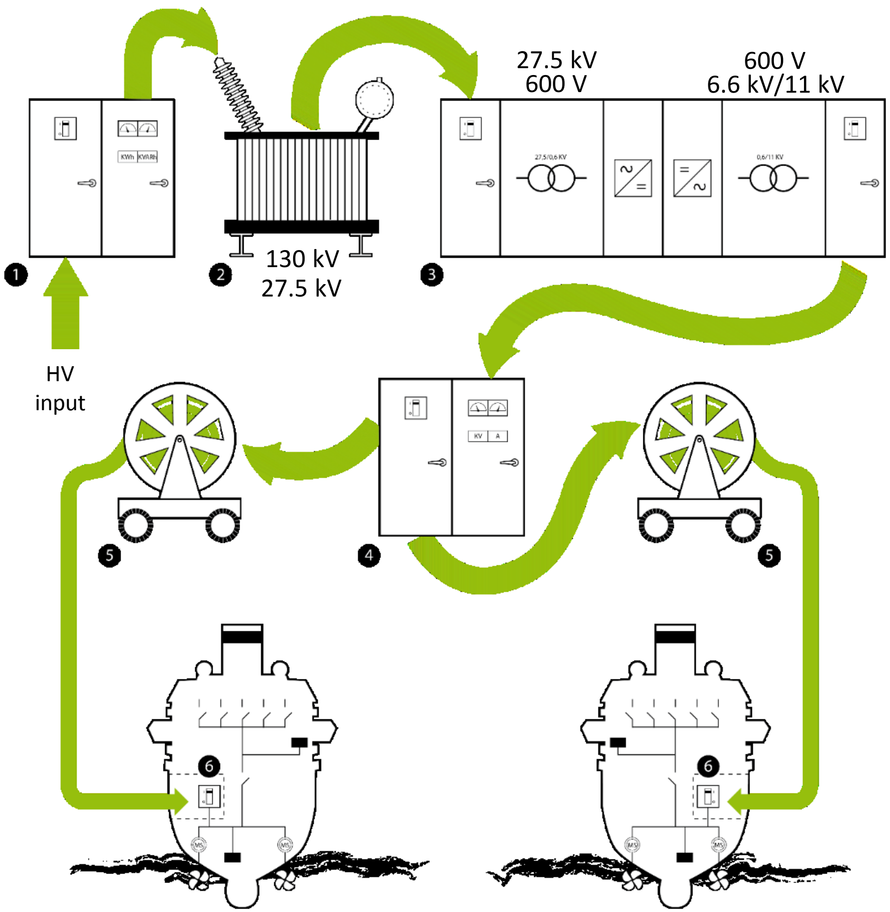
Cruise ship emissions (80.000 ton GT ≈Costa Mediterranea)

- NO_x emissions for 8 h berthing (12MW) ≡ 10.000 Diesel Euro V TS – Berlin
- 100.000 ships in 4.500 main ports (900·Mton CO2) ≡ 220 coal power plants

A possible solution: Cold Ironing

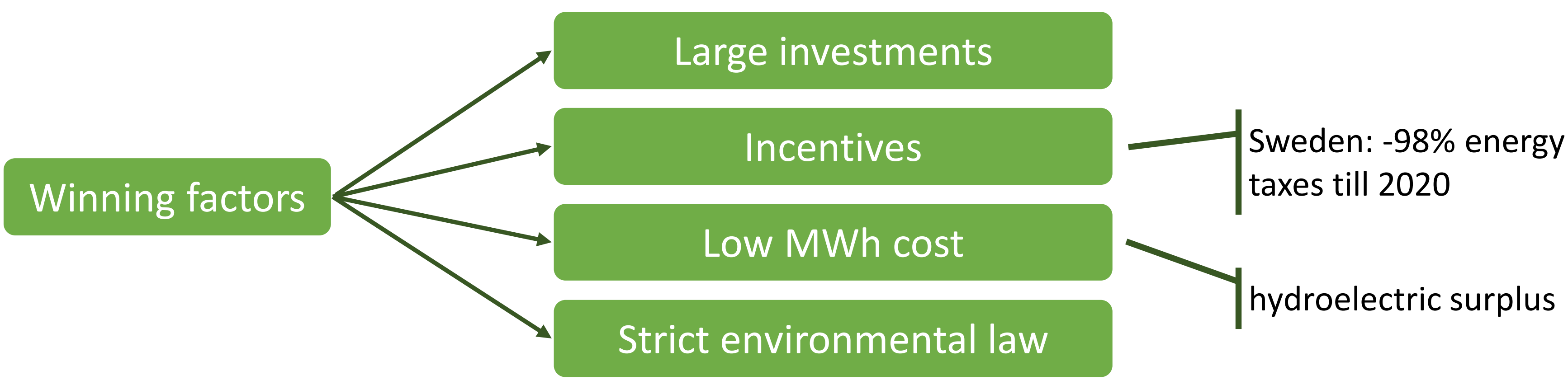
- Supplying the ship from the port electrical grid (HV shore connection)
- Operation time: from 15 to 45 minutes
- Standard IEC 80005-1: High Voltage Shore Connection (HVSC) Systems
  - from 1MW
  - from 1kV to 15kV AC (HV)
  - ship bus voltage: 6.6kV or 11kV (60Hz)
  - power for energy-consuming cruise: minimum 16 MVA, recommended 20 MVA

A possible solution: Cold Ironing



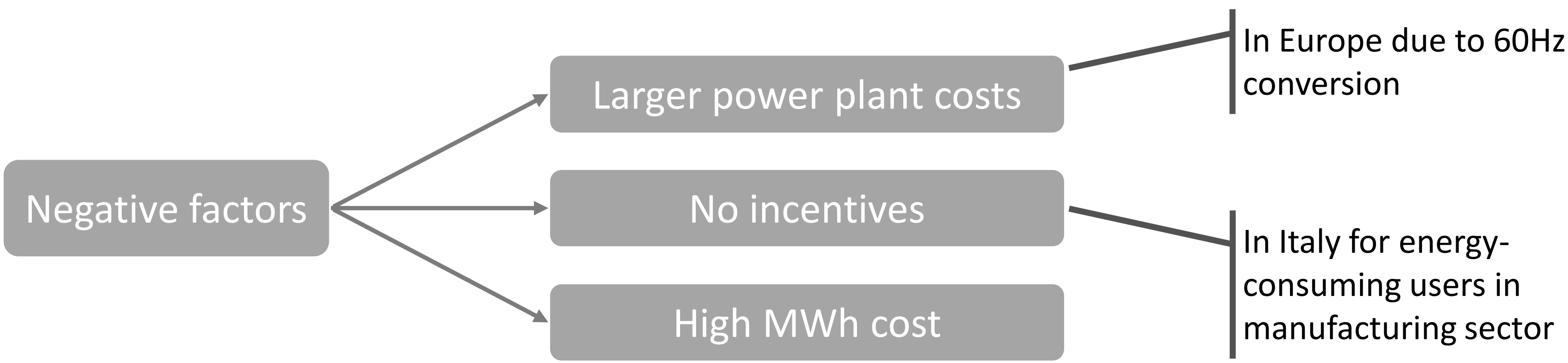
State of the Art – America and North Europe

- Mature technology for 20 years: Jeneau (16,2MVA), Seattle (16,2MVA), Vancouver (20MVA), Los Angeles (20MVA), Long Beach (20MVA), Goteborg (1989), Antwerpen, Helsinki, Stockolm…



State of the Art – South Europe

- Lots of projects (Genova, Venezia, Barcellona…), but few installations



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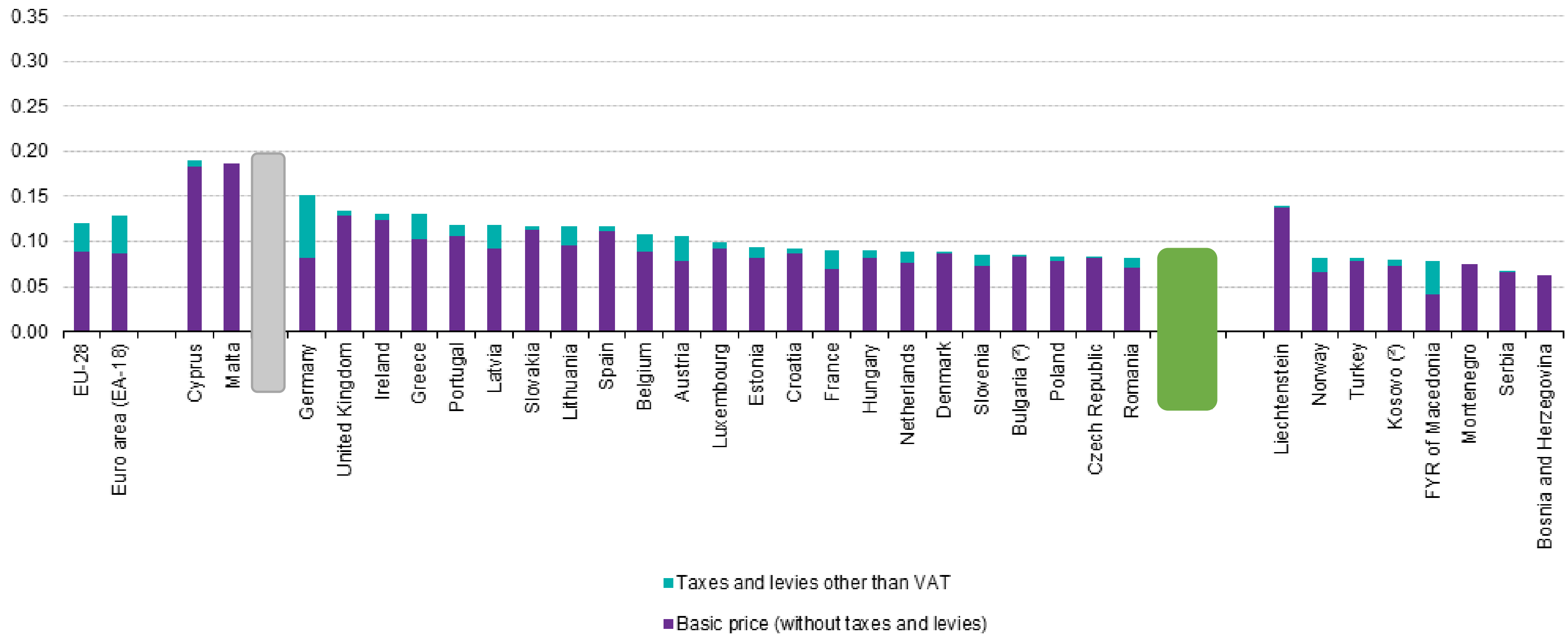
MWh cost in Europe



(¹) Annual consumption: 500 MWh < consumption < 2 000 MWh. Excluding VAT.
(²) Provisional.
Source: Eurostat (online data code: nrg_pc_205)

Starting point: the Port of Trieste

Strenghts

- important port
- deep sea bottom
- many industries in maritime field
- wonderful cruising terminal
- expected cruising terminal upgrade
- community sensibility (environment)
- increasing tourism
- technical/scientific know how

Weaknesses

- MWh cost
- cost for the electrical infrastructure
- for HV: cable duct realization
- need of an intensive cruising terminal use
- need of ship retrofitting

S W
O T

Opportunities

- available technology
- electrification of Porto Vecchio
- European funds
- new investments/opportunities
- international legislation support
- ports cluster for maintaining stops
- health disease reduction
- air quality improvement
- noise reduction
- electrification of transportation

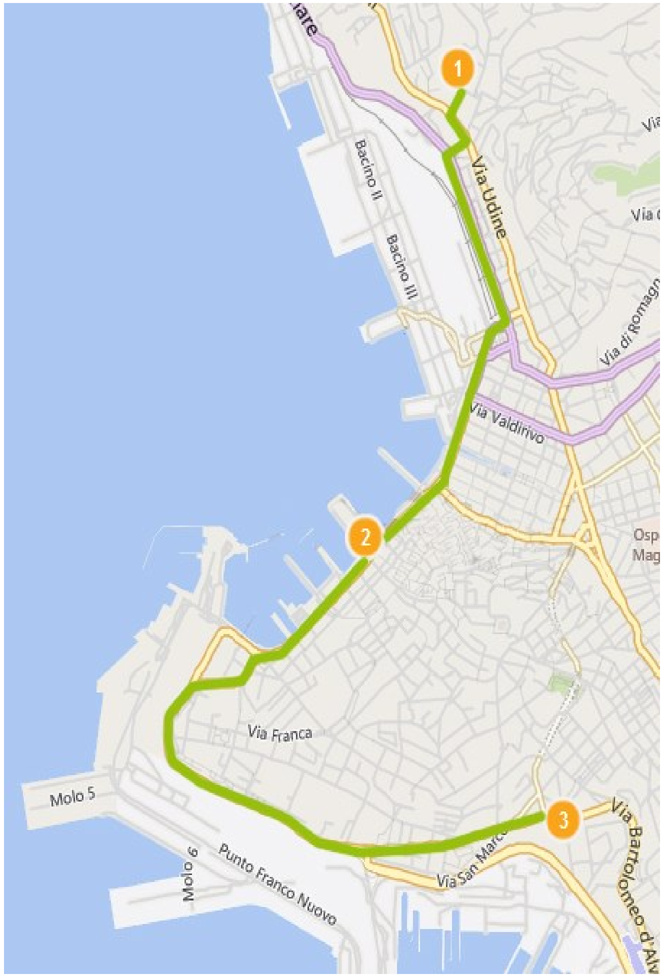
Threats

- few national funds
- absence of Mediterranean SECA areas
- low investments due to economical crisis
- time-consuming bureaucratic procedure
- politics susceptibility
- competition with large-close ports
- uncertainty in tourism flux

Starting point

Costs-benefits analysis for the Stazione Marittima HVSC:

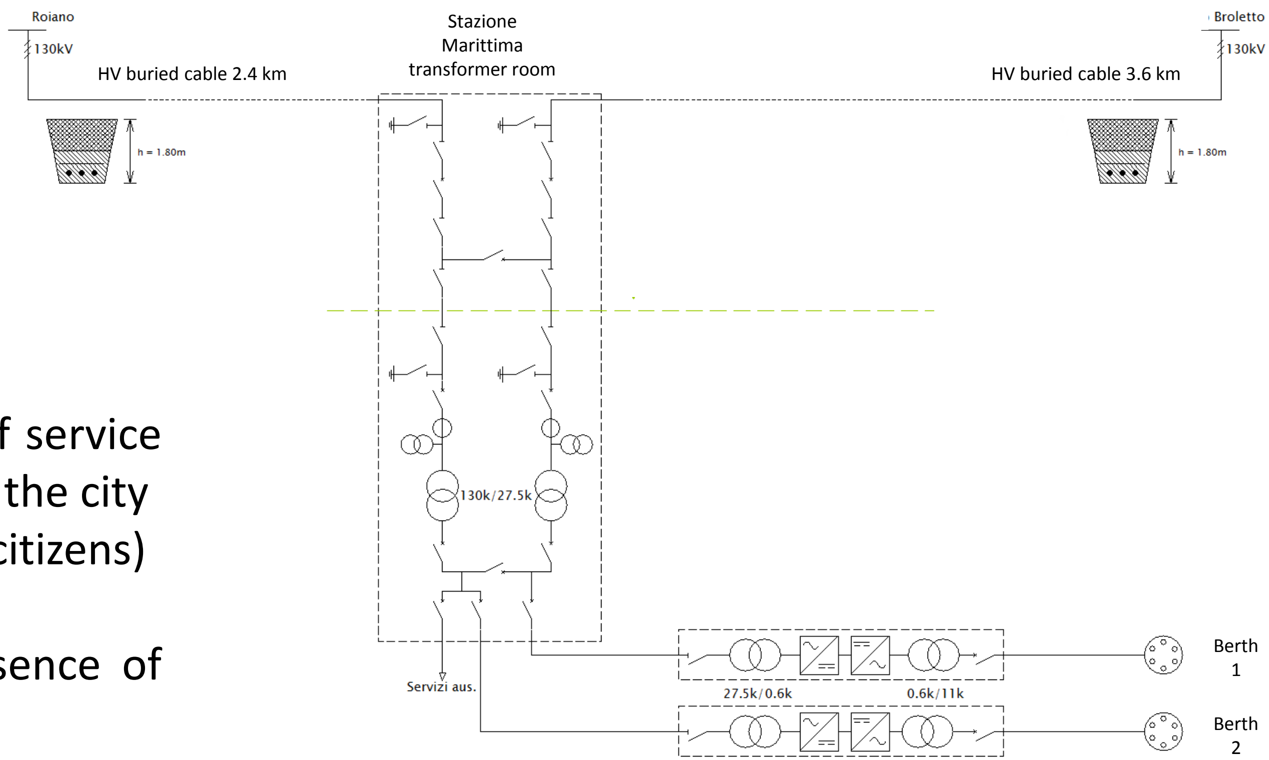
- 2 berths of 20MVA (HVSC1 and HVSC2)
- Suitable for an increasing cruise transport
- 130 kV loop from Valmartinaga (1) to Broletto (3)
- New transformer room in Stazione Marittima (2)
- 2 conversion systems (AC/DC + DC/AC)
- Total cost VAT included: about 30 M€



Starting point
HVSC Power System for Stazione Marittima

Additional pros:

- HV loop
- enhanced quality of service for the west part of the city (tens of thousands citizens)
- redundancy in presence of HV faults



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Estimate of the Infrastructure Costs

Element	N	Unity cost €	Total €
HV Delivery (SF6)	2	900.000	1.800.000
HV Cable	6 km	1.700.000	10.200.000
HV Switch	5	90.000	450.000
HV/MV Transformer	2	300.000	600.000
MV Switch	6	16.000	96.000
20 MVA Conversion Systems	2	4.000.000	8.000.000
Link	1	150.000	150.000
Designing Costs	20%		4.259.200
VAT	22%		5.622.100
Total			31.177.300

12.450.000€ + VAT (2.739.000€) may be shared among DSO and TERNA till the 50% (public interest)

15.730.000€ + VAT (3.459.000€) is up to the applicant (port) for the only shore connection

Aim of the Study

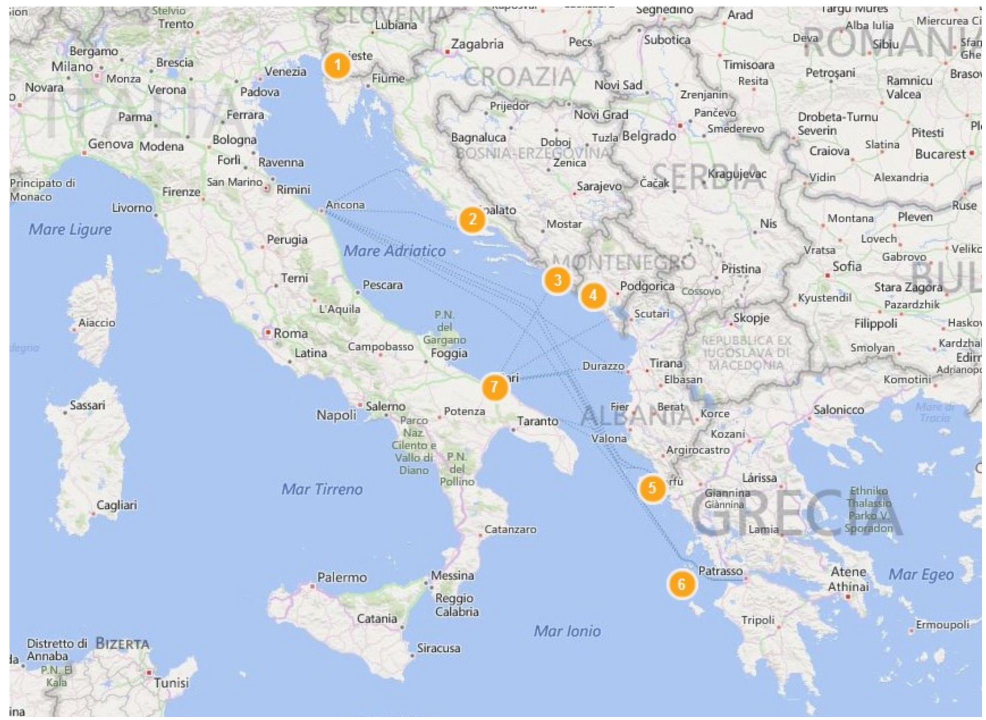
- To calibrate the starting design on the actual terminal needs
- To identify some points for evaluating the long-term HVSC feasibility
    - Design review
    - Environmental externalities
    - Running costs
    - Costs for ship owners
- Never only one port (Trieste), but an entire area (Adriatic-Ionian, Mediterranean)

Design Review (route)

The study is not limited to Trieste area, but it regards a cluster of ports (cruise lines).

Why?

1. Area point of view, not limited to a single terminal
2. Electrified route to justify the ship owner expenses
3. Green energy!
   Hydroelectric → Kotor
   PV → Bari
   Wind → Greece



Design Review (Installation costs)

- 2 (20 MVA) berths are overmuch: only 1 berth HVSC1 (16MVA→ new ships)
- During the installation of HVSC1, also HVSC2 requirements are taken into account

Element	N	Unity Cost €	Total €
HV/MV Transformer	2	300.000	600.000
MV Switch	6	16.000	96.000
16 MVA Conversion System	1	3.450.000	3.450.000
Link	1	150.000	150.000
Designing Costs	20%		3.470.000
VAT (also HV supply)	22%		4.050.000
Total (also HV supply)			21.177.300

7.760.000 + IVA (1.708.000€) is up to the applicant (port) for the only shore connection

Total with HV supply (previous hypothesis and costs)

Environmental Costs

- Environmental externalities (negative): costs (produced by an economical activity) responsible for a wellness reduction. Such costs impact on the community in terms of health expense.

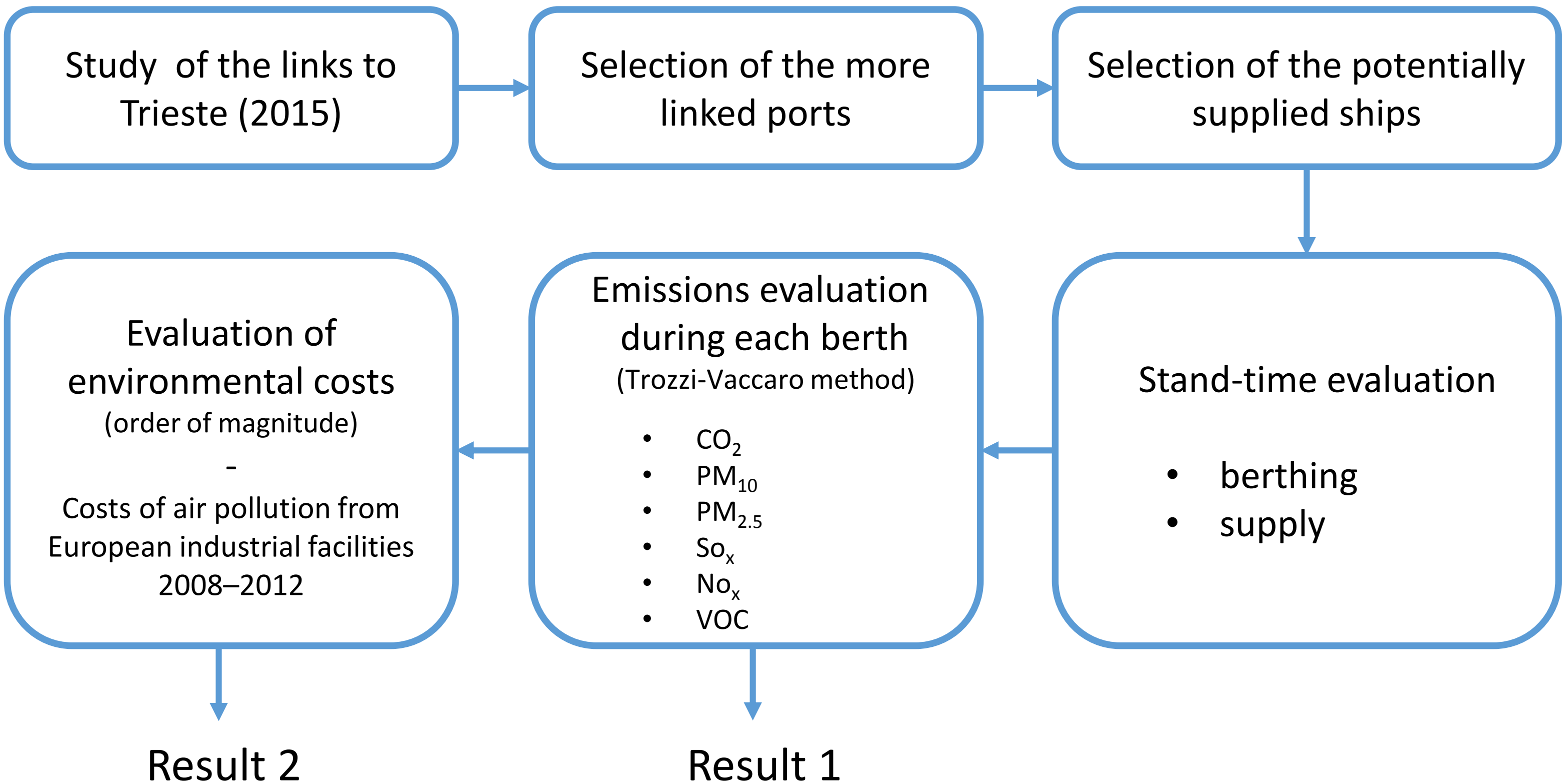
- Lot of studies have evaluated the health-environmental costs given by a polluting quantity

- Pros: estimation of the damage's order of magnitude

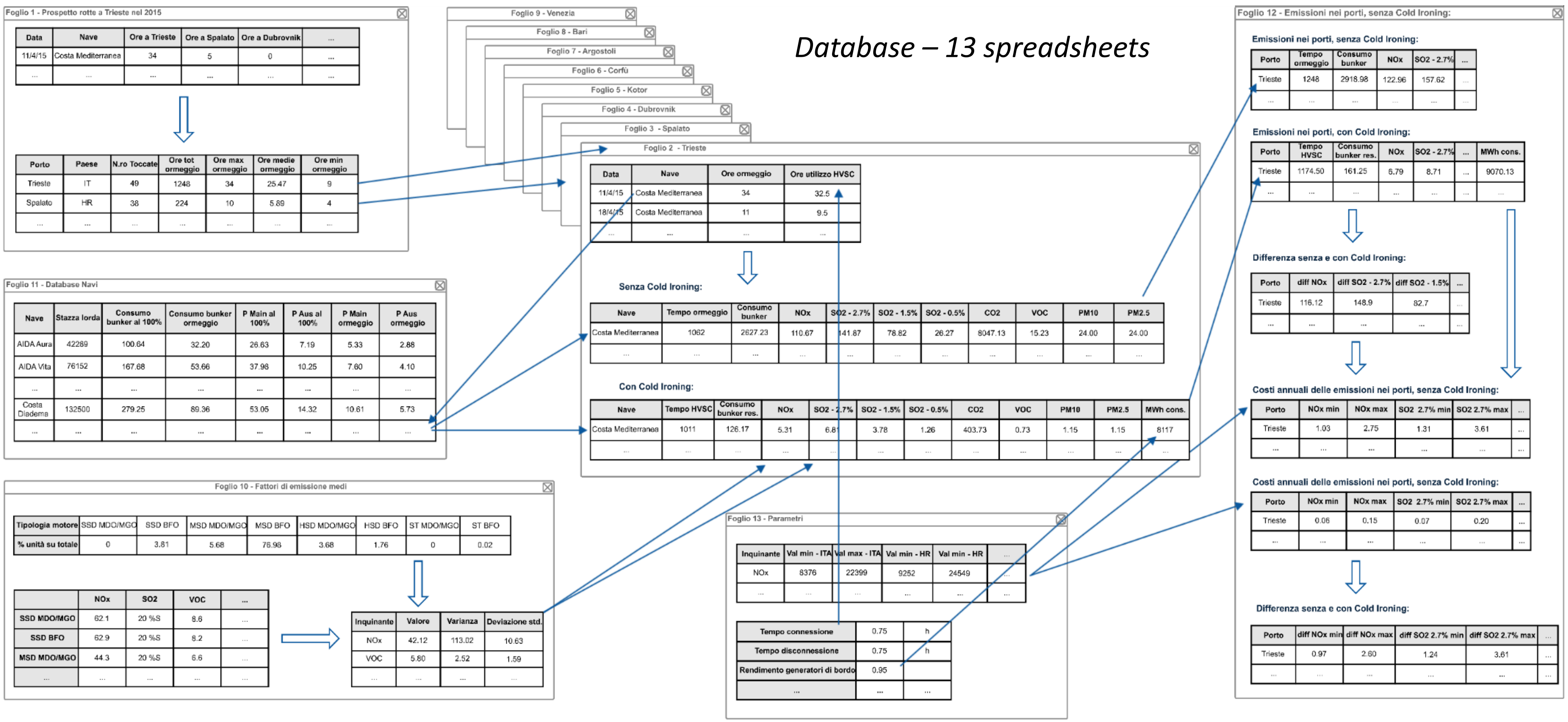
- Cons: high level of errors (30%) → Approximation into emission factors (e.g. kg Sox/ton bunker) → worst case: no dispersive model all emissions are falling down to the ground

- Goal: raise awareness about this issue

Procedure for Estimating the Environmental Costs



Database – 13 spreadsheets



Results - Emissions

How many tons/year of polluting emissions are saved by using HVSC?

Port	Hours	Δ NOx	Δ SO_x 2,7%	Δ SO_x 1,5%	Δ SO_x 0,5%	ΔCO_2	Δ VOC	Δ PM10	Δ PM2,5
Trieste	567,5	**52,9**	**67,8**	**37,7**	**12,6**	**4019,5**	**7,3**	**11,5**	**11,5**
Split	730,0	60,9	78,1	43,4	14,5	4626,6	8,4	13,2	13,2
Dubrovnik	2907,5	241,5	309,6	172,0	57,3	18344,8	33,2	52,4	52,4
Kotor	958,0	85,4	109,5	60,8	20,3	6487,1	11,8	18,5	18,5
Corfù	2108,5	166,0	212,8	118,2	39,4	12611,6	22,8	36,0	36,0
Argostoli	492,0	52,6	67,4	37,5	12,5	3995,9	7,2	11,4	11,4
Bari	499,5	64,3	82,4	45,8	15,3	4884,5	8,8	13,9	13,9

Results – Environmental Costs

How many M€/year of health/environmental costs are saved by using HVSC?

Port	Scenario 2.7%	Scenario 1,5%	Scenario 0,5%
Trieste	**2,39**	**1,95**	**1,58**
Spalato	1,73	1,37	1,07
Dubrovnik	6,85	5,43	4,24
Kotor	2,00	1,63	1,32
Corfù	2,30	1,92	1,61
Argostoli	0,72	0,60	0,50
Bari	3,11	1,97	2,12
Tot cluster	19,10	14,87	12,44

sulphur level

- Absence of a dispersive model

- Years of life lost (YOLL)

European Environment agency

Running Costs

- Running costs estimation evaluates the work economical sustainability during the entire life of the plant
- These costs take into account operation, maintenance, employees. Discount rate is assumed negligible
- Data elaborated with DSOs
- What is considered: HV line, main transformer room, converters
- Which is the service life (S.L.): 50Y for the HV line, 40Y per the transformer room, 25Y for conversion systems and link

Total and Annual Costs

DSO				HVSC manager			
Element	**S. L. (years)**	**Tot. cost (M€)**	**Cost/year (€)**	**Element**	**S. L. (years)**	**Tot. cost (M€)**	**Cost/year (€)**
HV line	50	2.5	50.000	HV/MV room	40	0.64	20.000
HV/MV room	40	1.42	35.000	Converters and link	25	5.41	216.000
Total in S.L.		**3.92**	**85.000**	**Total in S.L.**		**6.05**	**236.000**

Total cost (DSO+HVSC manager)

- Main cost is up to HVSC manager (both total and cost/year)
- Refundable by means a fee
- Employees operating on the link are largely affecting this evaluation

Costs for Ship Owners

Estimated by assuming the following hypotheses:

- Fuel consumption: 0,2kg/kWh
- Absorbed power: 16MW e PF 0,85
- 1062 hours of berthing, 1011 hours of possible use (year)
- Marine bunker price: 584.22€/MT without VAT and excise (worst case for HVSC)

Economical comparison - marine bunker vs HVSC

- marine bunker fuel

$$C_{NO\,HVSC} = t_{orm} \cdot C_{bunker} \cdot Pr_{bunker} = 1062 \cdot (0{,}2 \cdot 16) \cdot 584{,}22 \simeq 1.985.400\,€$$

- HVSC

$$C_{HVSC} = (t_{orm} - t_{HVSC}) \cdot C_{bunker} \cdot Pr_{bunker} + [E_{HVSC} \cdot C_{attiva} + E_{HVSC} \cdot \tan(\arccos(\varphi)) \cdot C_{reattiva}] \cdot 1{,}22 =$$

$$= (t_{orm} - t_{HVSC}) \cdot C_{bunker} \cdot Pr_{bunker} + P_{HVSC} \cdot t_{HVSC} \cdot (C_{attiva} + \tan(\arccos(\varphi)) \cdot C_{reattiva}) \cdot 1{,}22 =$$

$$= (1062 - 1011) \cdot (0{,}2 \cdot 16) \cdot 584{,}22 + 16 \cdot 1011((80 + 60{,}812) + \tan(arcos(0{,}85)) \cdot 8{,}6) \cdot 1{,}22 \simeq$$

$$\simeq 2.932.100\,€$$

Energy quote

Active energy excise

Reactive energy excise

VAT

Economical comparison - marine bunker vs HVSC

The HVSC solution cost is higher: 1 M€ is the difference. In absence of A3 component (50 €/MWh – renewable energy),

$$C_{HVSC} = (1062 - 1011) \cdot (0{,}2 \cdot 16) \cdot 584{,}22 + 16 \cdot 1011 \left((80 + 60{,}812 - 50) + \tan(arcos(0{,}85)) \cdot 8{,}6 \right) \cdot 1{,}22 \simeq$$

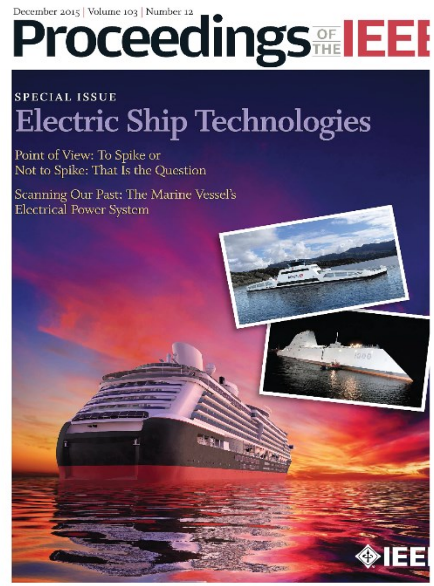
$$\simeq 1.992.600\,€$$

Cost equal to marine bunker case

- No cost for the GSE (new users typology)
- Only an intervention of energy policy!
- Anyway, the cost for installing the systems onboard is to be taken into account: about 1M€ for retrofitting

Remarks

- Relevant technical/scientific know-how



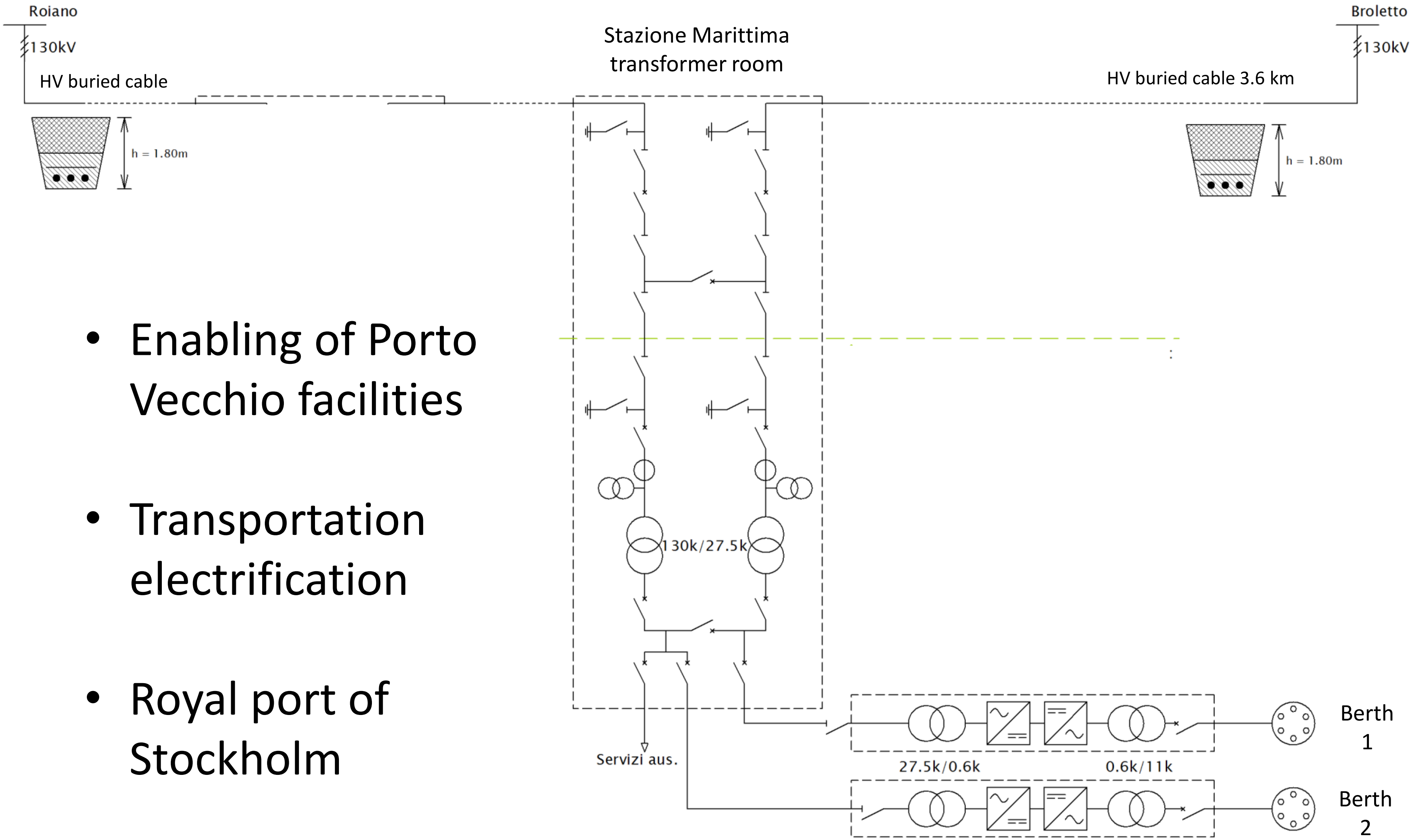
Sulligoi, G.; Bosich, D.; Pelaschiar, R.; Lipardi, G.; Tosato, F.;
"Shore-to-Ship Power"
Proceedings of the IEEE, Vol. 103, No. 12, pp 2381 - 2400, Nov. 2015.

- new electrical infrastructure (HV loop)

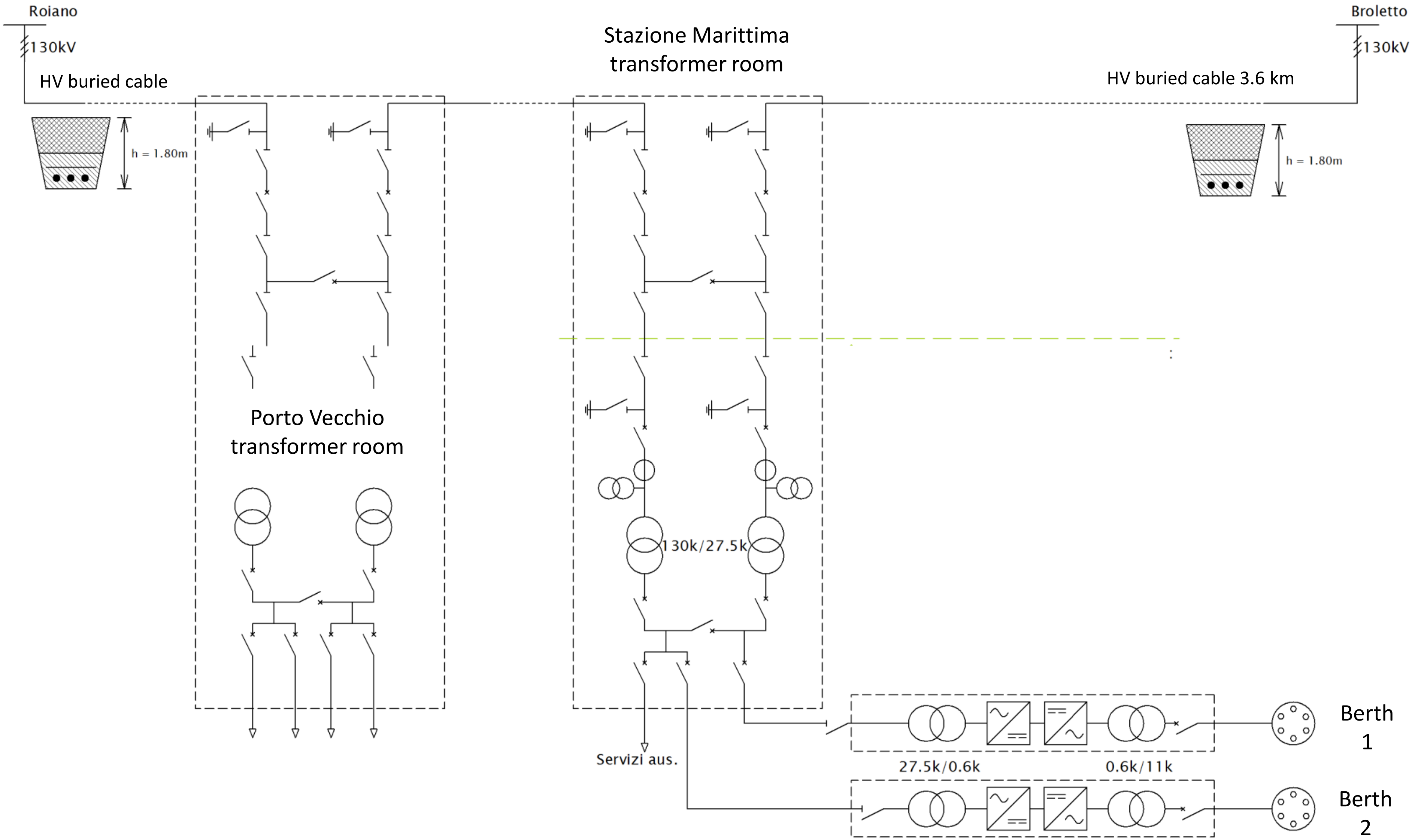
- redundancy in presence of HV faults

and last but not least....

- enhanced quality of service for the west part of the city



- Enabling of Porto Vecchio facilities
- Transportation electrification
- Royal port of Stockholm



Roiano
130kV
HV buried cable
h = 1.80m
Stazione Marittima
transformer room
Broletto
130kV
HV buried cable 3.6 km
h = 1.80m
Porto Vecchio
transformer room
130k/27.5k
Servizi aus.
27.5k/0.6k
0.6k/11k
Berth
1
Berth
2

Needs and Challenges [Porto Nuovo – Trieste]

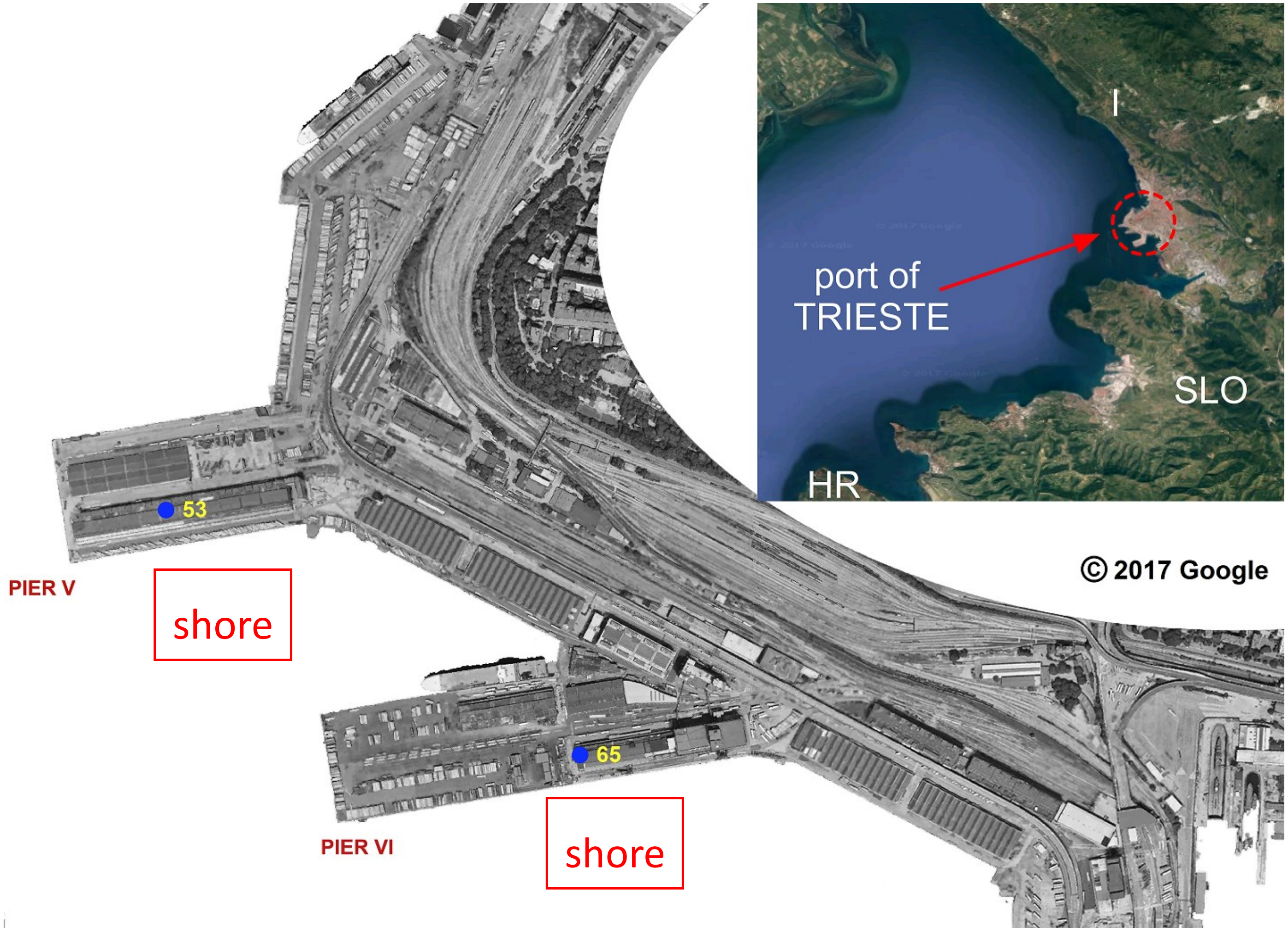
- Transition need: port distribution → port microgrid
  - safety
  - reliability
  - cost-effectiveness
- Advantages enabled:
  - Avoiding black-out eventualities
  - Enhancing/enabling advanced logistic services
  - Decreasing operating costs
  - Decreasing operating time
  - Cutting environmental emissions

EGREBUTY [Porto Nuovo – Trieste: UniTS/PTS]

Electrical GRid for grEen BUsiness continuiTY

- HOW?
  - Electrical distribution system upgrade
  - Control system upgrade
  - Railway-Docks electrification
- By
  - Analyzing the actual port infrastructure **(first stage)**
  - Developing a novel grid model **(!)**
  - Studying the power flows **(!)**
  - Conceiving Electrical Storage Systems **(!)**
  - Identifying a cluster of uninterruptible loads **(microgrid!)**
  - Controlling and re-configuring the microgrid **(final stage)**

First implementation? [Porto Nuovo – Trieste]



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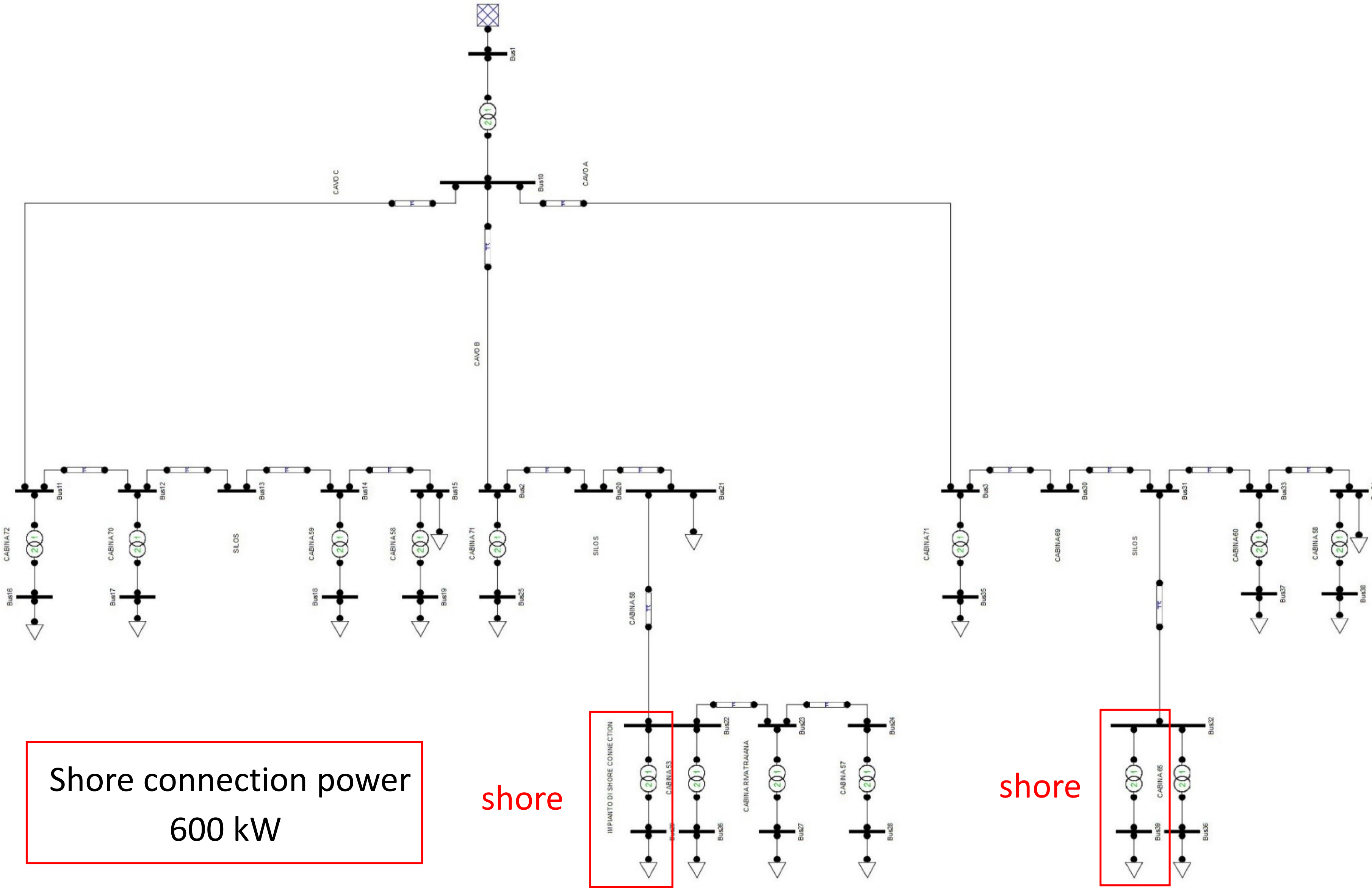

Shore connection power
600 kW

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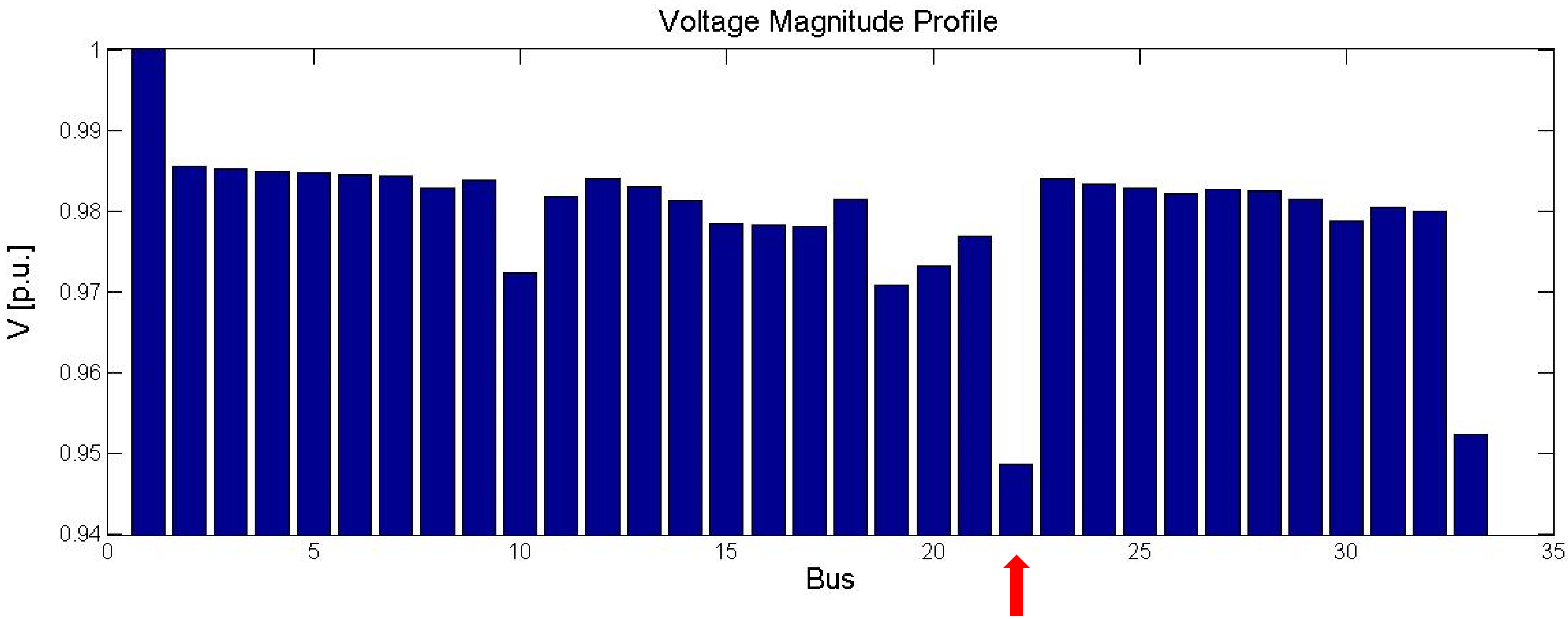
Trieste, March 9th 2018



0.948 p.u.

- Power flow analysis
- Voltage profile
- Acceptable dip in the most critical bus → **Feasible solution!**
- Pilot project evaluation (TBD): ro-ro ferries IT-TURKEY

Conclusions

- A cluster of ports has been identified to guarantee a high utilization of HVSC technology: Trieste, Split, Dubrovnik, Kotor, Corfù, Argostoli e Bari
- The ports with more traffic may be promoted
- Overall: -1.650 ton polluting and -55.000 ton CO_2 (cluster/year)
- Lower the emissions, higher the city attractiveness
- Lower the environmental costs, lower the costs for community (health)

Conclusions

- Infrastructure costs: non only the terminal, but re-infrastructuring a wide area
- Running costs are mainly given by conversion systems and employees
- By adopting the HVSC solution, the cost/year for ship owner are notable (145% of marine bunker solution)
- Such costs are sustainable without the A3 component (= marine bunker solution).

Conclusions

- Dedicated incentives/de-taxations can make sustainable the HVSC solution
- No conflict with LNG (synergic)
- Energy policy must have the main role in this issue
- Idea of a first feasible implementation (low power) at the Port Nuovo
- Low power pilot project

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Thank you for your attention!

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