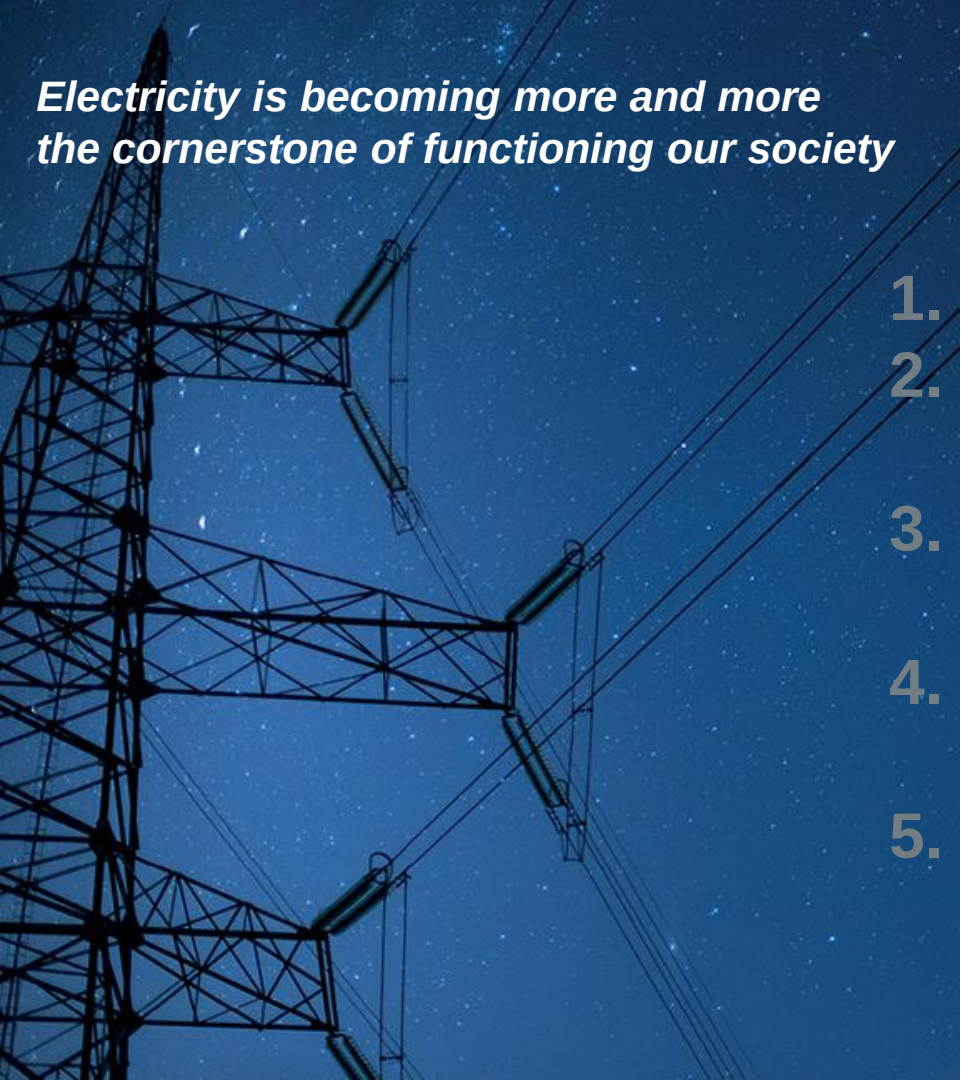
Workshop TGEG'19

»Comparison between early electrification grand transmission projects and the study of CIGRE C1.35 on Global Grid for 2050 from economic point of view«

Focus on increasing global interconnections and decarbonization

Kresimir Bakic, ELES, Honorary member of CIGRE, Paris
Aleksander Mervar, CEO ELES, Slovenia

Versailles, 27 June 2019



ELES

PLAN OF PRESENTATION

1. Intention of contribution
2. Early electrification & electricity affordability
3. Cigre study of Global grid with some indications
4. Decarbonization pathway, economy & grand projects
5. Conclusion

“A leader needs enough understanding to fashion an intelligent strategy.”
John Kotter, Harvard Business School

Intention of contribution

Importance of transmission

Experiences in different societies after dissemination process of Cigre WG C1.35 results on global

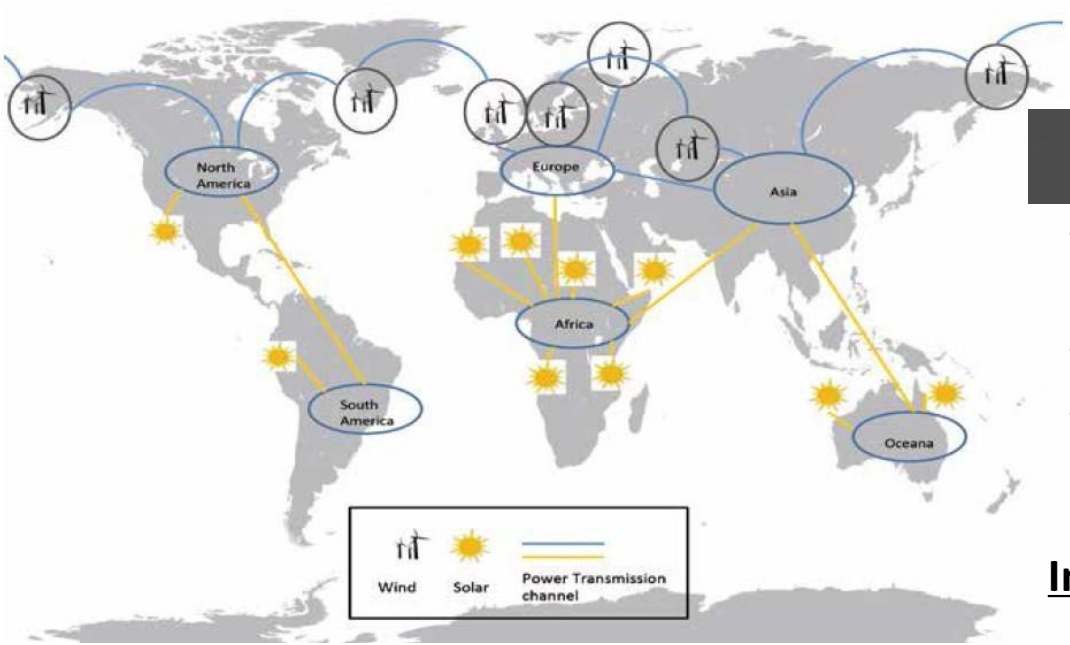
- *Very different views of thinking.*
- *Some doubts in the grand projects between continents,*
- *Some thoughts was talking about utopian projects,*
- *Some thoughts were very positive and believe it will be carry out in near future particularly due to reduction of CO_2 equivalent emissions.*

Question?

What we can learn from the past and what we can do for the future?

Marcus Tullius Cicero: “Historia magistra vitae est”/ "history is life's teacher".

Clean energy and interconnections



INTERCONNECTION CONCEPT

- **Supports a balanced coordination of power supply of all interconnected countries.**
- **Enables clean energy transmission**
- **Take advantage of diversity of clean energy.**

Increase clean energy consumption

Source: CIGRE WG C1.35

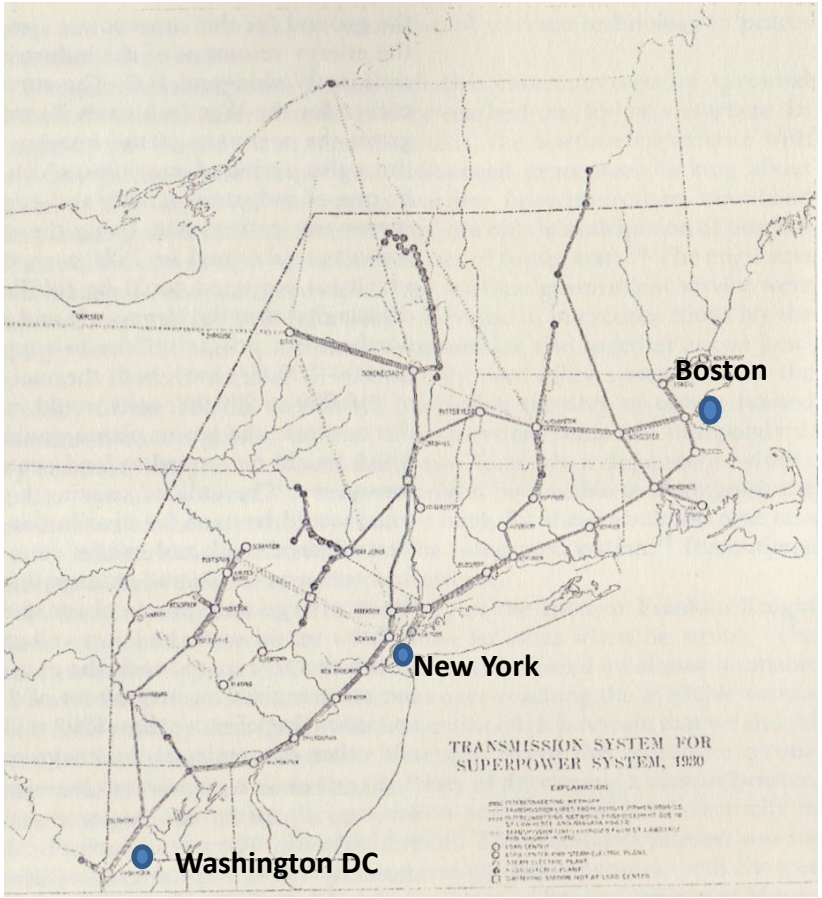
"Strategy means making clear-cut choices about how to compete."

(Jack Welch, Chairman, and CEO of GE)

2.0

Early electrification & electricity affordability

A Superpower System for the Region between Boston and Washington DC



***William S. Murray**, Dept. of the Interior, US Geological survey, paper 123, W,DC, GPO, 1921), Ref. 5 (T. P. Hughes)*

Plan for Superpower system was projected for 1930 with size of 60-300 MW (TPP,HPP) + Transmission 110 kV/220 kV…….*Murray estimated that, compared with the cost of an unintegrated system supplying the same region, an investment of 1 billion $ would result in an annual savings of more than **$200million** because of higher load factor and other economies of integrated system*……..**20% savings**

Global electricity production in 1900 was **12 TWh** and In 2000 about **20.000 TWh**.
Who open the door to electrification? **INNOVATIONS**
1. CONDUCTORS stranded AL conductors 1899, ACSR… 1907, AAAC…1939
2. INSULATORS: New type of suspension and strain types, June 1907….first OHL over 100 kV
3. GENERATORS: 1911…Ludwig Roebel (BBC, Mannheim) Invented stator bars for turbo generator – special method for windings by limiting eddy currents and enables first large generators over 20 MVA.

Pan-European Transmission network project by Oscar Oliven, from 1930

2nd World Power Conference in Berlin, 1930. German engineer Oscar Oliven proposed pan-European 400 kV Transmission network of 9 750 km. Evaluated cost of investment for T&G was 240 billion CHF for 20GW load.

Value of USD in 1930 was equal 5,16 CHF

Value of USD in 2019 is almost equal 1 CHF.

European grand projects in early time of electrification were:

-**Georges Viel ,** 3000 km, 400kV, 79GW, 10,4 GCHF, sav. (10%)

-**Ernst Schőnholzer,** 3800 km, 660kV, 6.4 GW, 25GCHF, sav. 24Mt

-**Oscar Oliven,** 9750 km, 400kV, 20GW, 240 GCHF

Comparison Oliven's project vs. CIGRE C1.35

1 USD (1930) = 15 USD (2019) con. consumer price index+inf.

Oliven's project re-evaluated to 2019 value:

Production capacity**: 20 GW**

Annual generation**: 100 TWh**

Annual cost**: 70 GUSD**

Total specific cost**: 700 USD/MWh (610 EUR/MWh)**

Electricity was very expensive and not attainable for all.

CIGRE C1.15 GG_i project evaluation in 2019:

Production capacity**: 14 920 GW**

Annual generation**: 40 300 TWh**

Annual cost**: 1820 GEUR**

Total specific cost**: 48 EUR/MWh**


entsoe
Interconnected network of Continental Europe
2017
(as of 31.12.2016)
Scale: 1 : 2 500 000
NORTH SEA
BALTIC SEA
ATLANTIC OCEAN
BLACK SEA
CASPIAN SEA
MEDITERRANEAN SEA
ADRIATIC SEA
REPUBLIC OF IRELAND
ESTONIA
LATVIA
LITHUANIA
BELARUS
RUSSIA
KAZAKHSTAN
UKRAINE
GEORGIA
ARMENIA
AZERBAIJAN
IRAN
TURKEY
SYRIA
IRAQ
CYPRUS
LEBANON
ISRAEL
JORDAN
SAUDI ARABIA
MALTA
ALGERIA
MOROCCO
TUNISIA
HUNGARY
MONTENEGRO
ALBANIA
MONACO

1975 – Competitive project for Southern Europe / to build coal TPP or import hydro energy from large HPP Inga (Congo river)

Project made by prof. Vladimir Slebinger in Ljubljana, Slovenia

Possibility for electricity production in the river Congo are about 1125 TWh

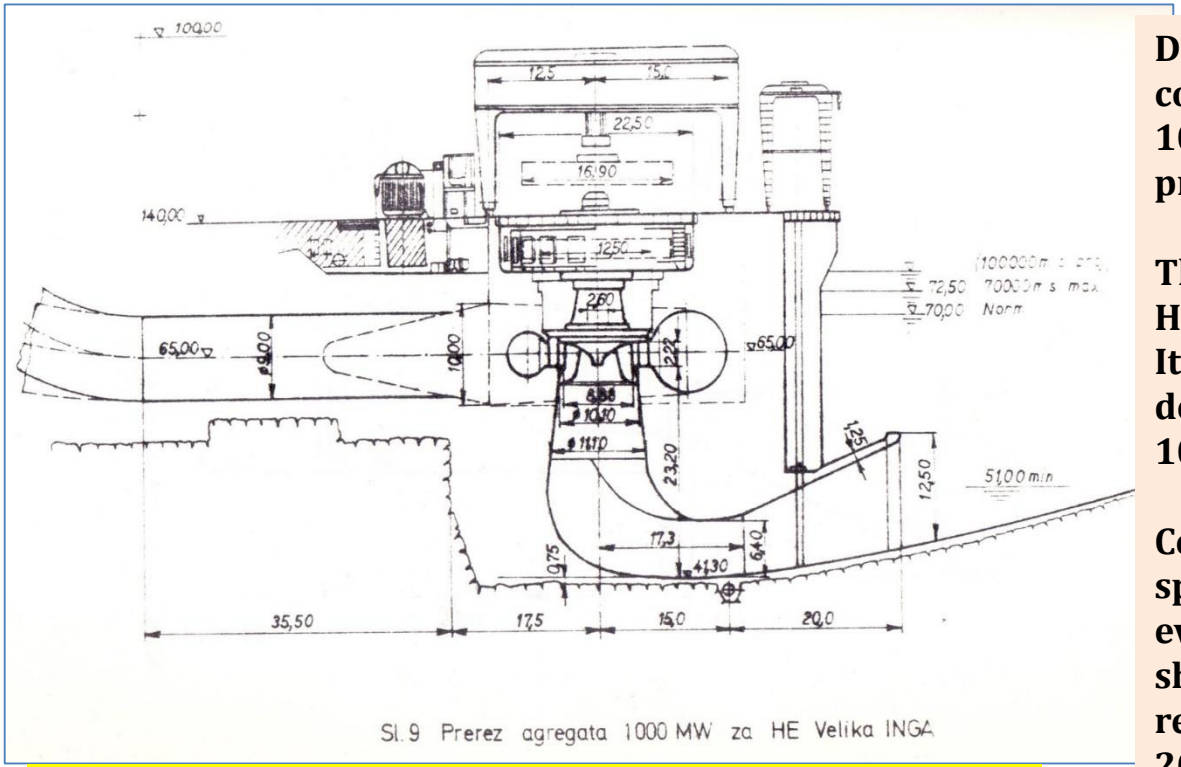
Very short history of the INGA project and researches:

- **1926/1928, Van Deuren, first Belgian project: HPP1 (351 MW) + HPP2 (3150 MW)**
- **1960, Second Belgian project Abelinga (Brussels): 28.850 MW (210 TWh) with Grand Inga dam.**
- **1971, Reconstruction of the project and increasing instalation on 39.680 MW (288 TWh), with water flow 33.000 m^3/s.**
- **1975, New variant with increasing on 300 TWh, with calculating cost of 5 USD/MWh.**
- **With same condition of loans would be cost of energy from z Grand Inga about 8x less thanat HPP Djerdap or Asuan.**

Slebinger's new project in 1975

His proposal for **60 GW** in 1975 considered environmental conditions from that time, new ideas for the units of **1000 MVA**, transmission with **±1500 kV**, new concept for submarine cables for deep sea, conversion of AC/DC/AC with thyristors, what was very new for that time.
price for new TPP in Southern Europe. Considering very low consumption in Sub-saharian Africa he proposed 80% of production of electricity for new industry in Africa and transit of surpluses to Europe. In study , he considered 5 African evacuation cones (N. Africa, Egypt, Israel, Central Africa, S. Africa) and 3 zones for transit to Europe: Direction WEST (Spain + France), EAST (TR, CY,GR) and CENTRAL direction from Tunis to Italy.

PROJECT OF DR. VLADIMIR ŠLEBINGER in 1975



Sl. 9 Prerez agregata 1000 MW za HE Velika INGA

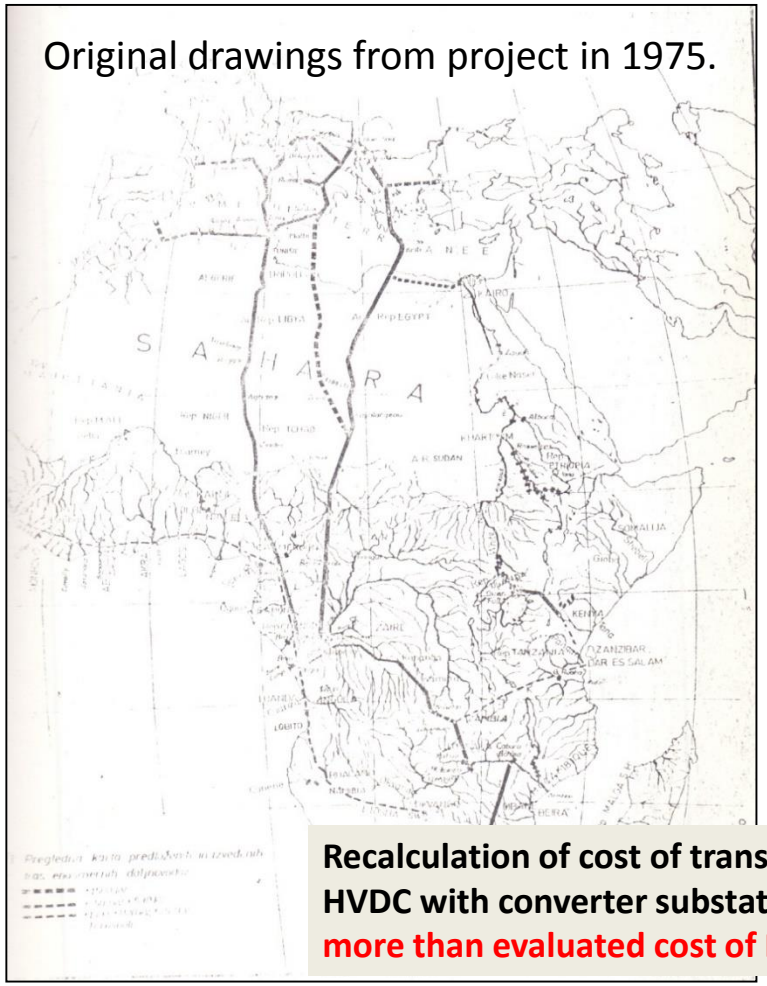
Sheme for 1000 MVA unit za Hydro power plant Grand Inga

Differently from other proposals he conceived GRAND Inge HPP for 60 X 1000 MW = 60.000 MW with annual production 365 TWh and LF=0.7.

The largest units in both today largest HPP in the world (Three Gorges & Itaipu) have units of 700 MW and today designers try to make concepts for 1000 MW units.

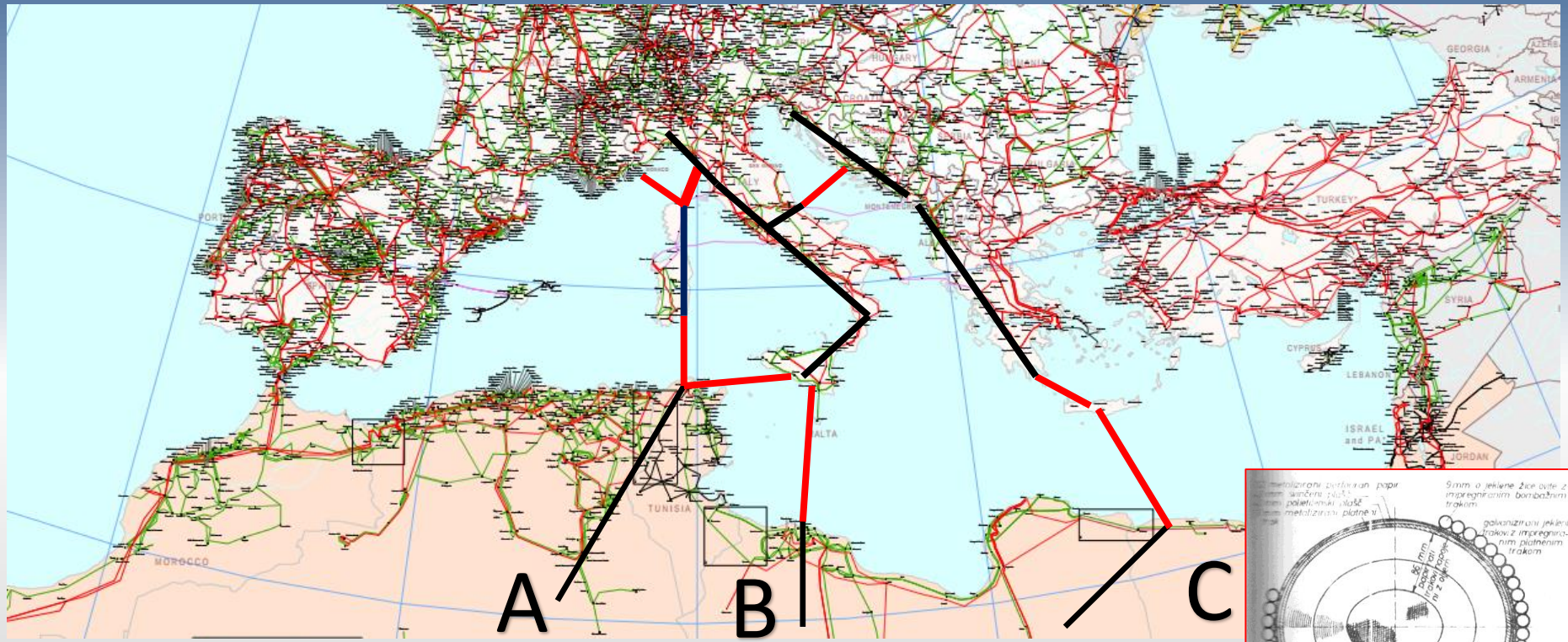
Considering to his evaluations of the specific cost for producing MWh and re-evaluate to the present time, the cost should be 14.5 USD/MWh (considering re-evaluation of USD from year 1975 to 2019).

Original drawings from project in 1975.



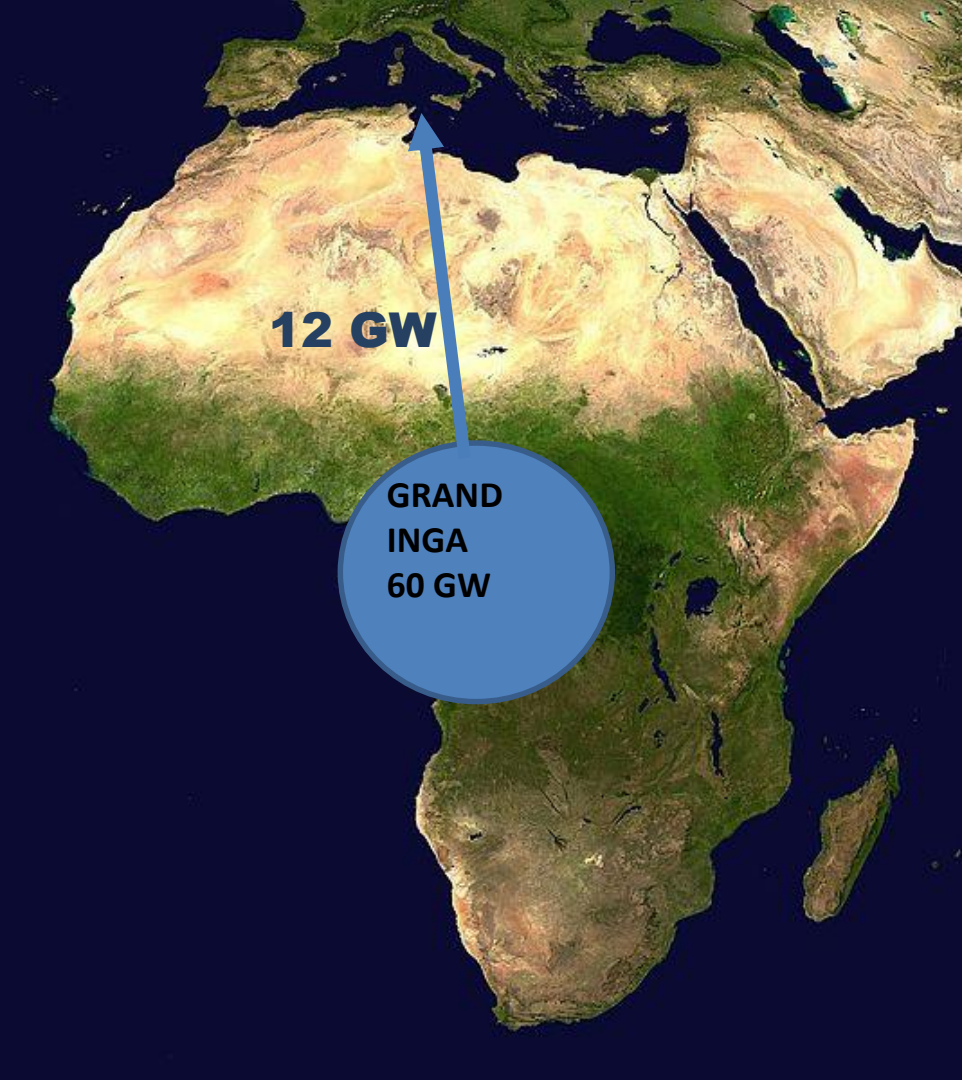
Recalculation of cost of transit for 6400 km distance with ±1500kV HVDC with converter substations was 60 USD/MWh or 4 times more than evaluated cost of MWh in HPP Grad Inga.

Interconnections between Africa and S. Europe in the Slebinger's project



Slebinger's project of transit 12 GW to Southern Europe in 1975 anticipated three submarine cables from Africa to Europe. Many years later (2018) in MedTSO project was designed crossing Mediterranean sea on similar way.

He designed oval profile of submarine cables



GLOBAL HYDRO POTENTIALS:
Gross potential : 38.600 TWh/a
Technicaly possible to use for HPPs: 14.600 TWh/a
Economical potential for HPPs: 8.770 TWh/a
Total production in 2016: 4.110 TWh (47%)
Average globally utilized: 47 %
Average utilized in Europe: 45 %
Average utilized in Africa: 13 %

Africa represent 20% of surface of Earth and is larger than Europe, USA and China together.
In Africa there are 50% of global hydro potentials and Congo river presenting almost half.

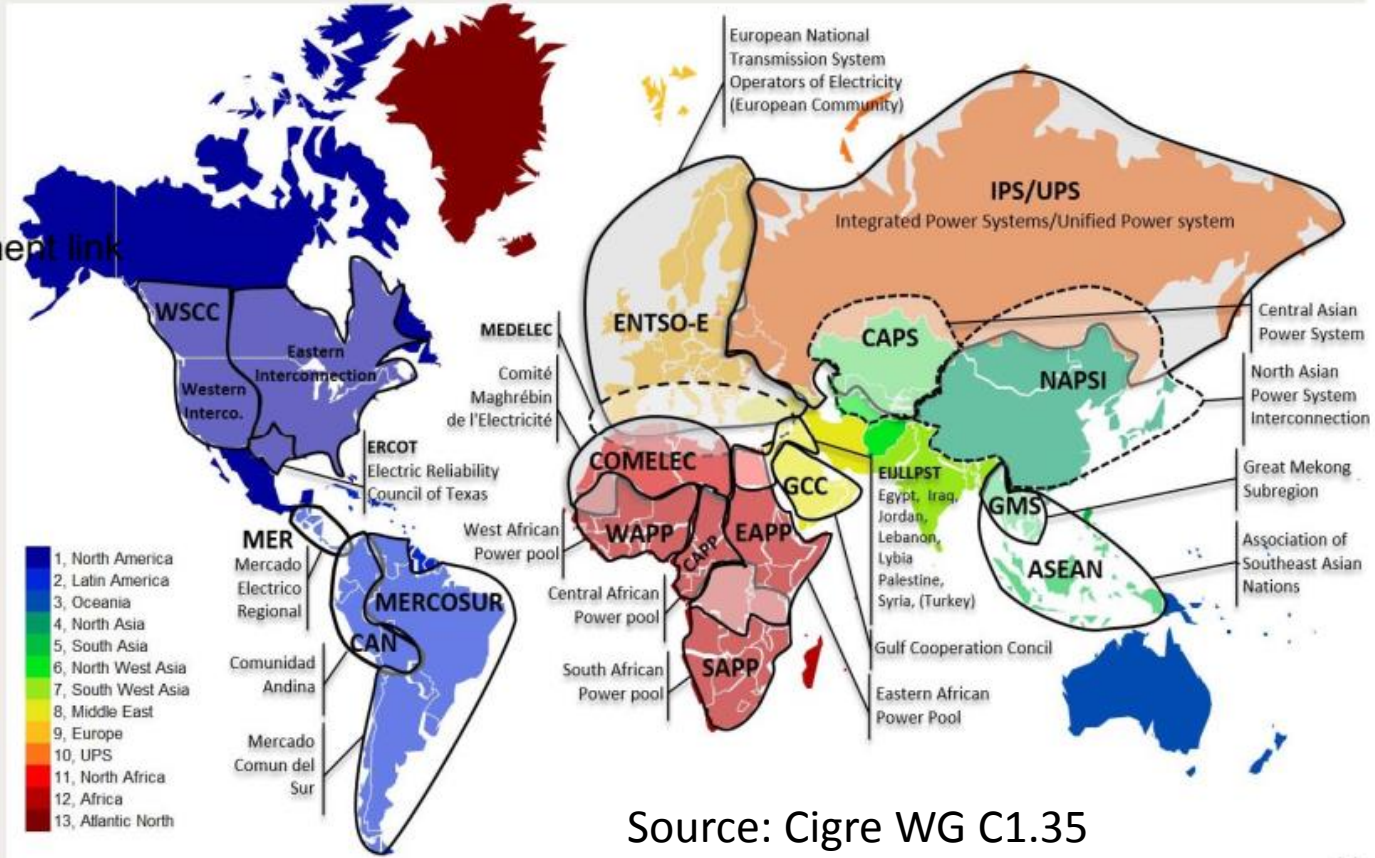
Global decarbonization goals should be a great opportunity for better utilization of the world hydro potentials.
Great projects from past could be re-designed and prepared as *unified global program for decarbonization* of energy sector.

3.0

Cigre study of Global grid with some indications

Regional initiatives

- Motivations:
  - Reliability/Security
  - Sustainability
  - Competition
- Different stages of development link mainly to political issues
- Compromise between national independency and an international weigh provided by an Economic Community
- In 2050, 13 zones seen internally as “copper-plates”



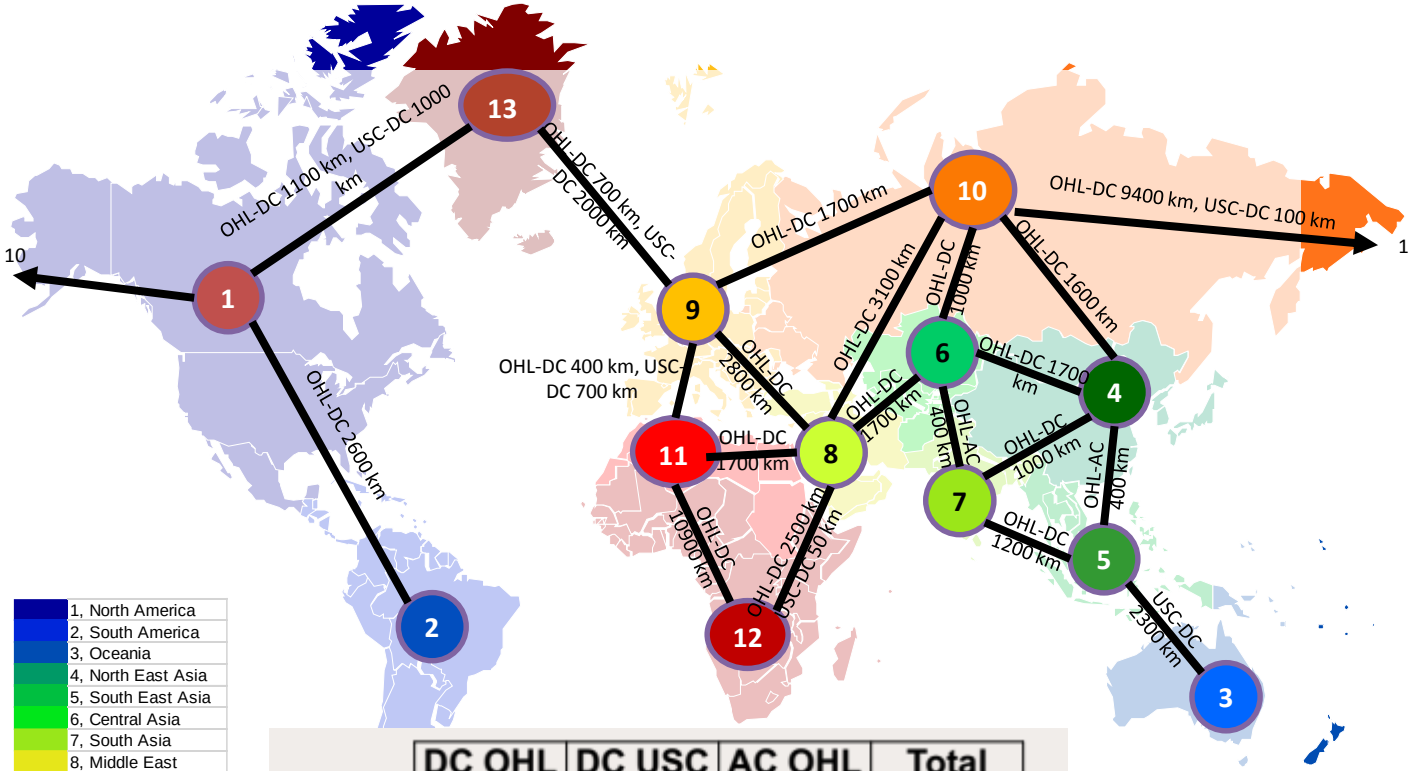
Source: Cigre WG C1.35

North Atlantic – Europe – UPS – North Africa – Middle East

Europe – North Africa – Middle East – UPS – Central Asia – South Asia

Interconnections selected

20 interconnections, mainly DC links, and OHLs technologies.



	DC OHL	DC USC	AC OHL	Total
km	85 801	15 100	1 600	102 501
%	83%	15%	2%	100%

cigre
For power system expertise

Comparison between non-integrated and integrated intercontinental global electrical grid

YEAR 2050	Gen capacity GW	Generation TWh/a	Total cost/a G€	Cost €/MWh	RES %	$CO_{2\ equiv.}$ Mt/a
GG_o	13 500	39 850	2 150	54	53	850
GG_i	14 920	40 300	1 820	48	76	343
Difference	+10%	+1.1%	-8.5%	-11%	+23%	**-60%**

Integrated global grid is a good option for global decarbonization goals.

This is very good message of CIGRE study to the one of the most challenging task of present and future generation of engineers.

“However beautiful the strategy, you should occasionally look at the results.”
Winston Churchill (1874–1965)

4.0

Decarbonization pathway, economy & grand projects

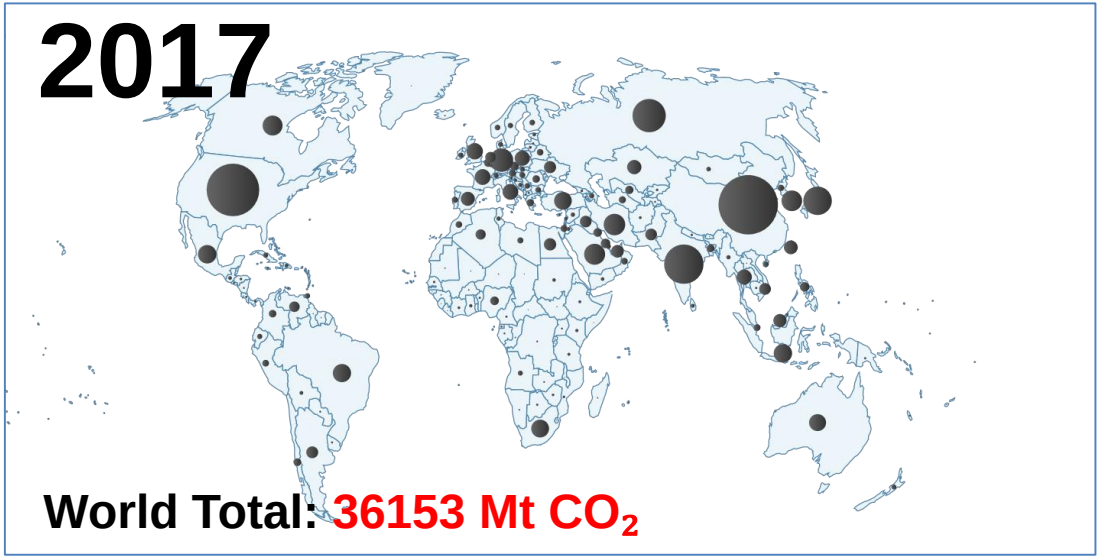
What is present global situation?

CIGRE study C1.35 considered WEC scenario („Unfinished symphony“) with global average emissions (2050) per capita: **2 tons/a**. How to reach this level of emissions? ***Do we have Global grand projects for this goal?***

Emissions CO_2 equivalence

10 highest in the world

Country	Emissions CO2	population	tons/capita
1. China	9839 Mt	1 409 millions	6,99
2. USA	5270 Mt	324 millions	**16,27**
3. India	2467 Mt	1 330 millions	1,85
4. Russia	1693 Mt	144 millions	11,76
5. Japan	1205 Mt	127 millions	9,49
6. Germany	799 Mt	82 millions	9,74
7. Iran	672 Mt	82 millions	9,20
8. Saudi Arabia	635 Mt	33 millions	**19,24**
9. S. Korea	616 Mt	52 millions	11,85
10. Canada	573 Mt	37 millions	**15,49**

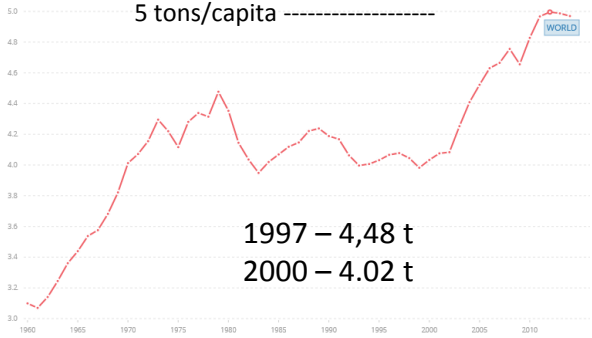


Source: Global Carbon Atlas (http://www.globalcarbonatlas.org/en/CO2-emissions)

Global averages ton per capita = 4.5

After 2012 (4.99) decline to 4.5-4.6

Source: WB



Decarbonization pathways – EU strategy

SOURCE: Eurelectric

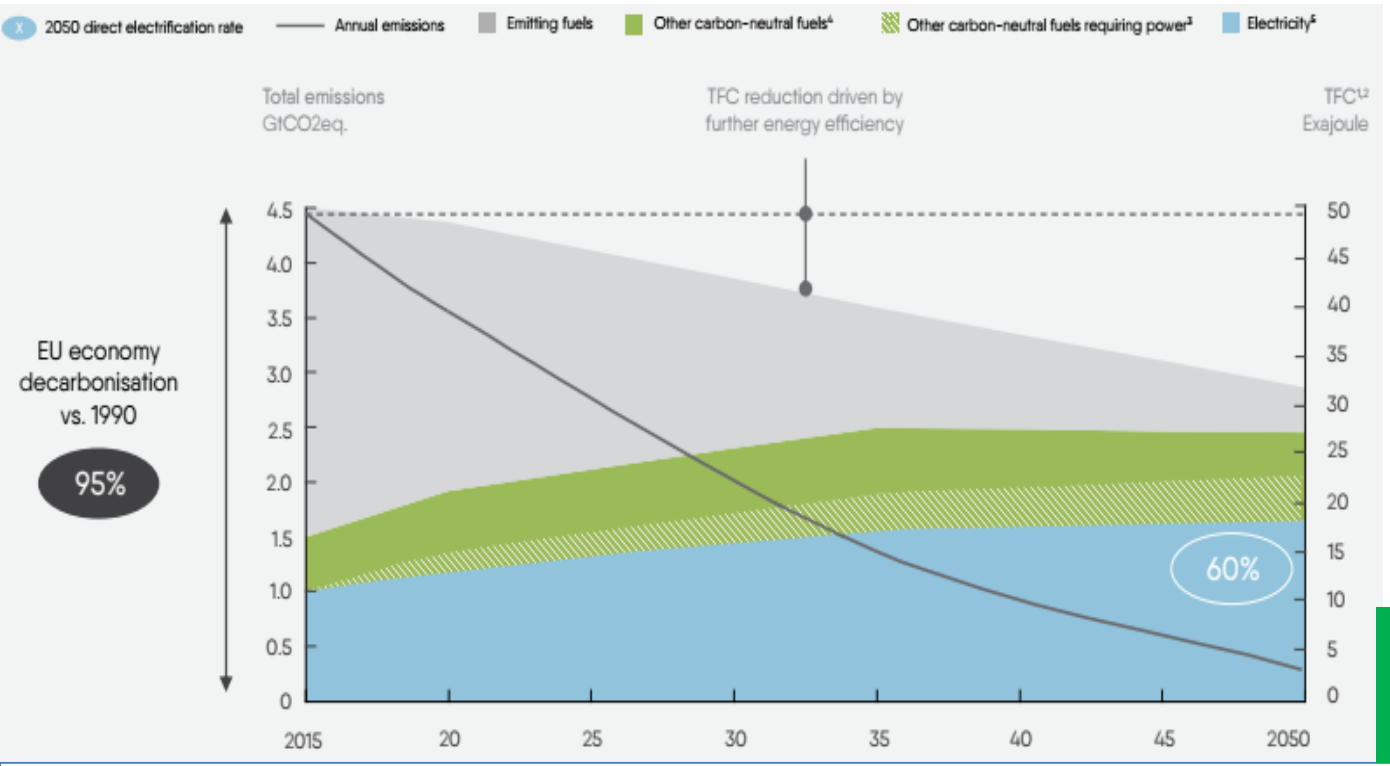
WITH ELECTRIFICATION THE EU CAN REDUCE 80 - 95% OF CO2 EMISSIONS BY 2050

EU emissions in 2016:

- Energy production....1.09 Gt (23%)
- Transport ....1.15 Gt (25%)
- Buildings .... 0.52 Gt (11%)
- Industry .... 0.59 Gt (13%)
- Non-energy source ....1.26 Gt (28%)

Electrification as main pillar for EU decarbonization.

Decarbonization is a global problem; solutions are missing with broad Global collaboration, grand projects on RES investments and business models.



SOURCE: Eurelectric

EU approach plan

WHAT WILL BE NEEDED TO ACHIEVE THIS AMBITIOUS TARGET?

1. **Political commitment** to deep decarbonization across all regions and sectors of the economy is critical…stronger coordination across European regions.
2. **Active involvement of citizens** in a more decentralized power market will be a key enabler.
3. **Co-operation between economic sectors** will be important to make use of synergies …
4. **Efficient market-based investment frameworks** and adequate market design to address the investment of high RES system.
5. **Smarter and reinforced distribution grid** will play an important role in integrating new market participants …

5.0 Conclusions

What we can learn from the historic and newest grand projects?

- **Grand Transmission projects from historic point of view have shown benefits for all, economic, technical and operational, increasing reliability and reinforcing the market conditions. In some historic cases it was evidenced reduction of total needed generating capacity up to 20%.**
- **Strengthening of transmission network brings cheaper electricity and better affordability. Extending continental macro-interconnection systems to intercontinental network will enables better conditions for decarbonization, as one of the most challenging tasks.**
- **Message of the CIGRE study C1.35 on Global Grid was very positive presenting many interesting results enabling further study on possible business models and market designs.**
- **CO_2 price (carbon tax) is a crucial driver for determine economic viability of the global interconnections.**
- **Decarbonization pathway should be taken more systematically considering global collaboration, new projects and also all ways of human life in the Earth.**

References:

1) Global electrical network – feasibility study, WG C1.35, Cigre, 2019.

*2) W. J. Hausman, P. Hertner, M. Wilkins: **GLOBAL ELECTRIFICATION**, Multinational Enterprise and International Finance in the History of Light and Power, 1878 – 2007. Cambridge University Press, 2008.*

*3) Vincent Lagendijk: **Electrifying Europe**, The Power of Europe in the construction electricity network, Amsterdam: Aksant DOI: 10.6100/IR638264, 2008.*

*5)T. P. Hughes: **Networks of Power**, Electrification in Western Society, 1880-1930, The Johns Hopkins University Press, 1983.*

6)Historical electricity data 1920-2017, UK
www.gov.uk/government/organisations/department-for-business-energy-and-industrial-strategy/about/statistics

7) W.S. Murray: A Superpower System for the region between Boston and Washington, Washington, Government printing office, 1921

Thank you

"Vision without action is a day dream. Action without vision is a nightmare."

Anonymous