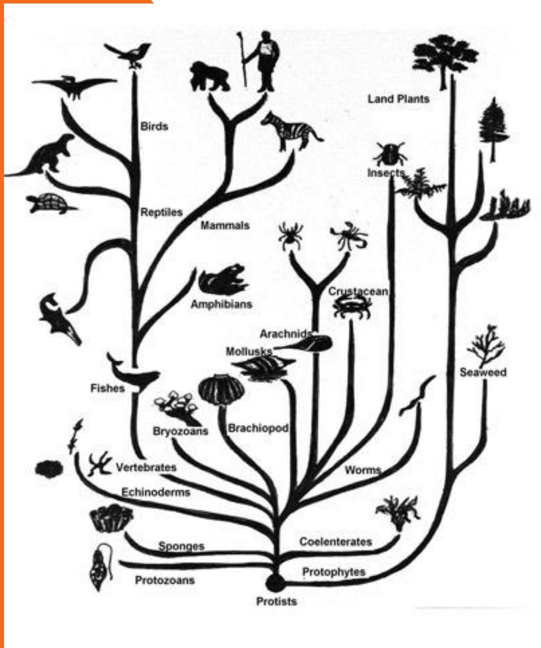
대한전기학회

진화론적 의미에서 본 에너지 전환의 의미와 승리의 길

2020년도 추계학술대회

2020.10.22.(목) ~ 24일(토)

제주 오리엔탈호텔



Prof. Jaeseok Choi, PhD

EE, Gyeongsang National University

jschoi@gnu.ac.kr

http://pwrsys.gsnu.ac.kr

ORCID ID : 0000-0003-0867-6251

I.What is Energy Evolution?

II. Why? : Situation & Direction (way forward)

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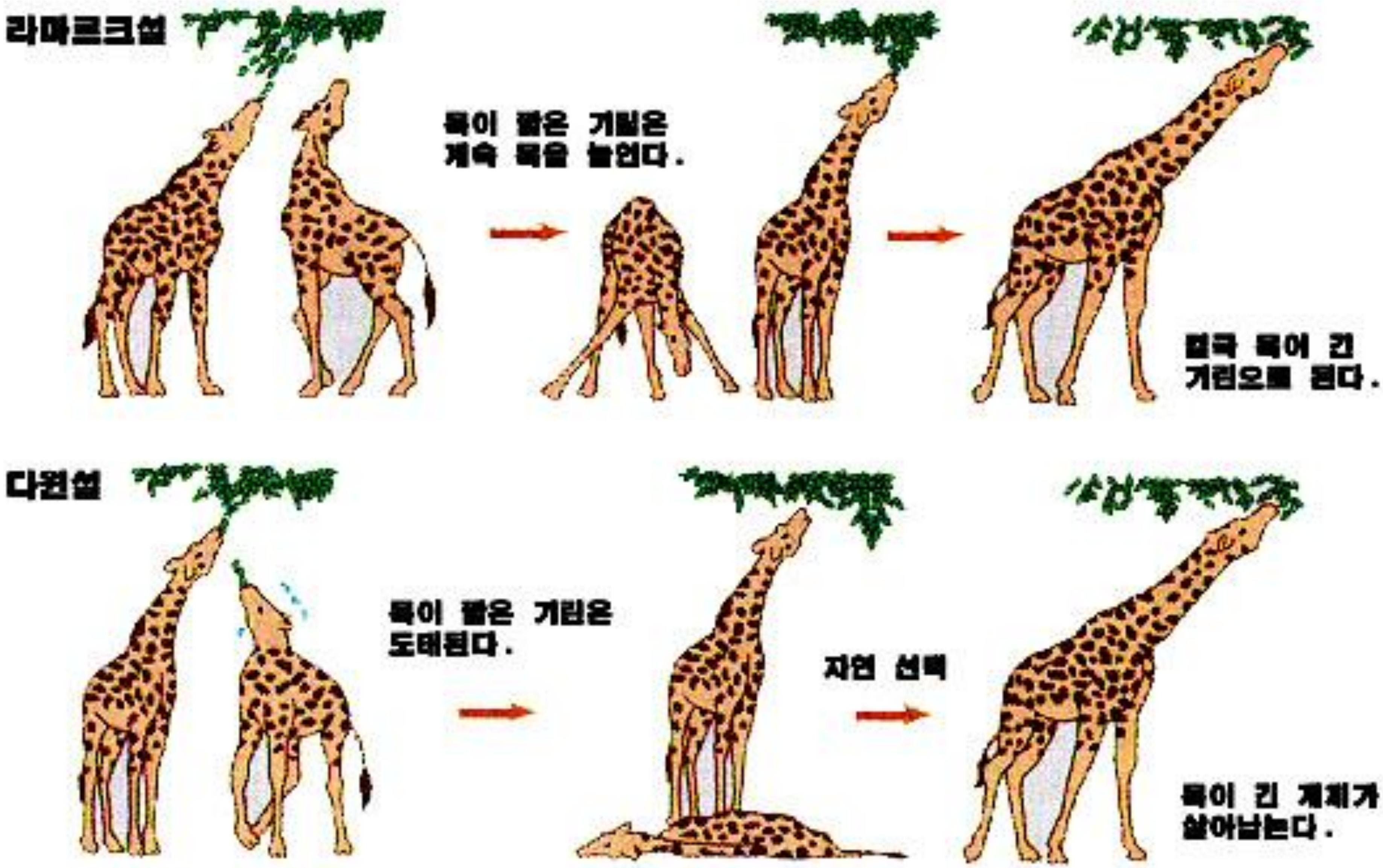
VII. Summary and Discussion

I. What is Energy Evolution?

(에너지 진화(Energy Evolution) 란 무엇인가?)

- 에너지도 DNA를 가진다.
- 그 에너지 DNA는 환경의 적응력에 따라 생존과 도태된다.
- Cross Over 교배(융복합)한다.
- 교배(융합)시 돌연변이가 발생한다.
- 돌연변이 시에 생존력이 특별히 뛰어난 유전인자(DNA)가 발생할 수 있다.
- 4IR (4차 산업혁명의 요소)들과 융합시에는 우세 유전인자 (DNA)가 만들어짐. Why?


라마르크설
목이 짧은 기린은
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다윈설
목이 짧은 기린은
도태된다.
자연 선택
목이 긴 개체가
살아남는다.

적자생존

결국은 적응하는 자가

살아남습니다

좋은날

시월의 새 책. 이정훈이 옮긴 허버트 스펜서(Herbert Spencer)의 ≪진보의 법칙과 원인(Progress: Its Law and Cause)≫

모든 것은 나아간다

씨가 나무가 되고

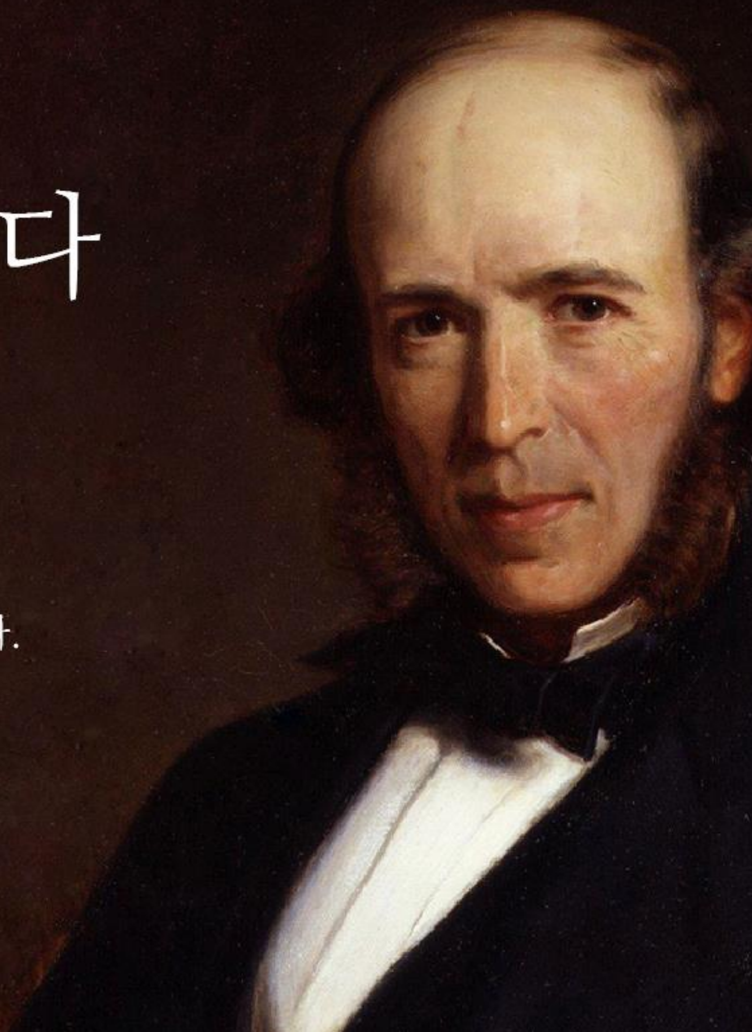
수정란이 성체가 되고

물고기는 인간이 되고

하나의 먼지 덩어리가 태양과 행성과 위성이 되었다.

생명에서 문화까지,

단순한 모든 것은 점점 더 복잡해진다.



<허버트 스펜서 초상화>, 존 배그놀드 버제스 그림, 1871~1872

II. Why? : Situation & Direction
(에너지 진화의 상황과 방향)

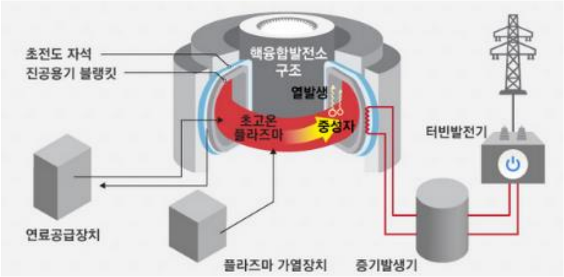
- 그 특성상 人類의 進化론과 매우 類似함.
- 인류의 진화는 변화하는 환경에 적극적으로 適應하고 이에 同意(順應)하면 生存함.
- 동의하지 못하면 淘汰됨.
- Energy 進化도 매우 類似함.
- 생존과 도태의 갈림길은 環境變化에 積極적으로 適應하는가? 긍정적 반응!과 부정적 반응!

Power Generation Time Chart

- 最初: 1860년대 후반, 프랑스, 제노브 테오필 그람
- 1868: 수력발전소, 잉글랜드, 암스트롱 남작, 지맨스 다이나모
- 1878: 화력발전소, 바이에른주 에탈, 지그문트 스추거트
- 1882년9월 Edison, 뉴욕시, 대규모화력발전 110VDC 탄소선 전구
- 1948년 9월: 미국 테네시주 오크릿지, X-10, 흑연원자로
- 1954년 6월: 구소련 오브닌스크, 흑연감속 비등경수 압력관형 원자로
- 1956년 10월 17일: 영국 셀라필드 원자력 단지, 콜더홀(Calder Hall) 원자력 발전소, **최초 상업용**
- 2020년: 현재; Which one is going to be a winner? Is REG a winner?

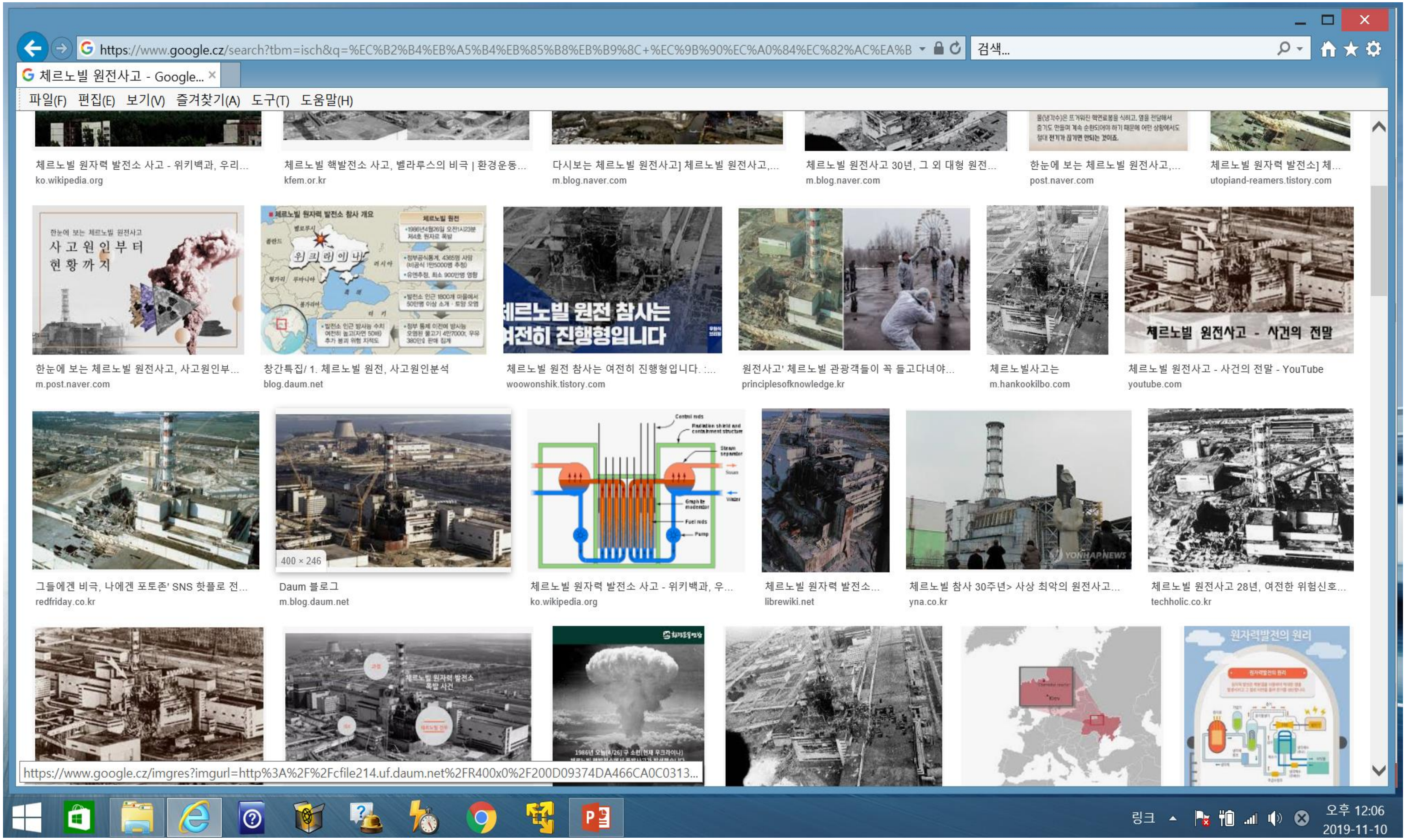
*** What Makes Money? (Business Model) ???**

- 2070년?: Nuclear Fusion Generation is the one?

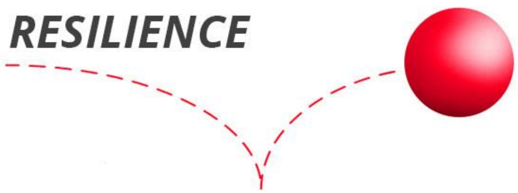


Coal Power Plant?

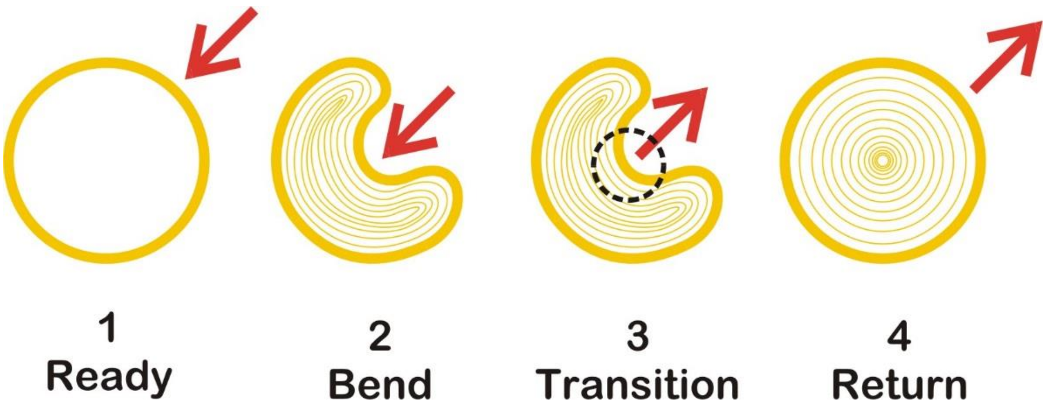
Nuclear Fission Generation?



Survival and Resilience?
(생존과 복원력)

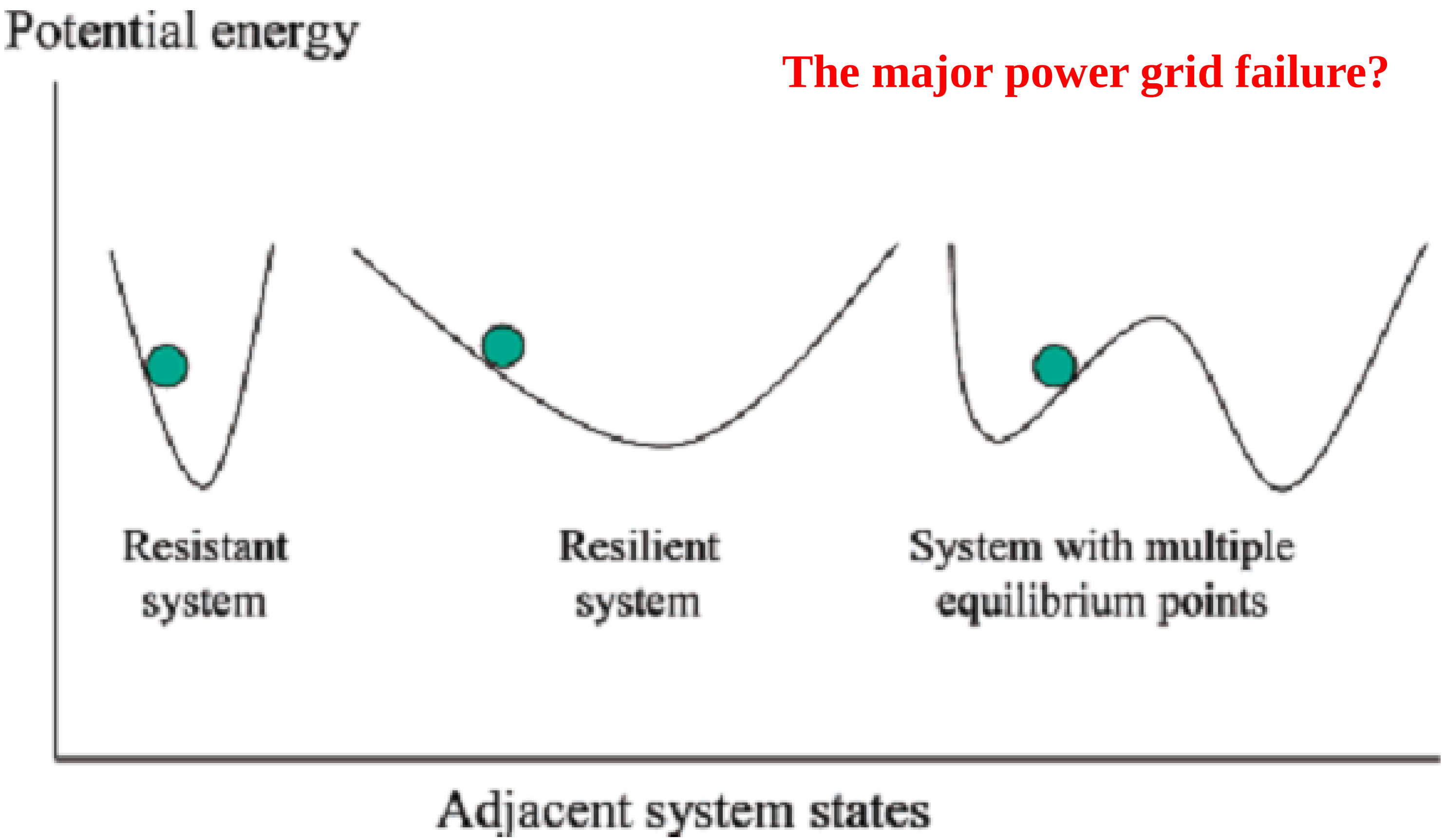


Resilience is understood as a system's ability to absorb a significant negative change or stress and recover from the stress to an acceptable degree of performance (Hoffman, 2008:37).



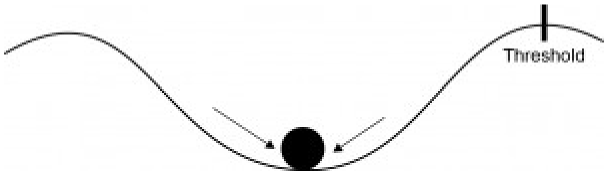
- Resistant systems operate within a narrow range of possible states, and are designed to resist perturbations from its equilibrium point.
- Resilient systems can function across a broad spectrum of possible states and gradually tends to return to its original state (equilibrium point)
- Systems held with multiple equilibrium points can tolerate larger perturbations

The major power grid failure?

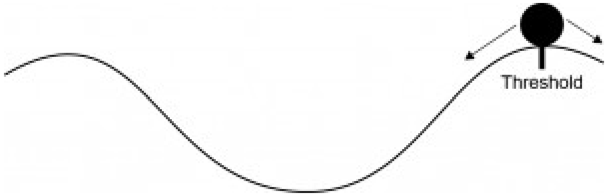


Ball-in-basin illustration of resilience

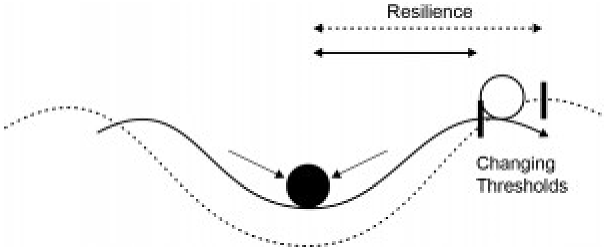
A **stable, resilient system** can cope with shocks and disturbances, and keep <u>its place</u>.

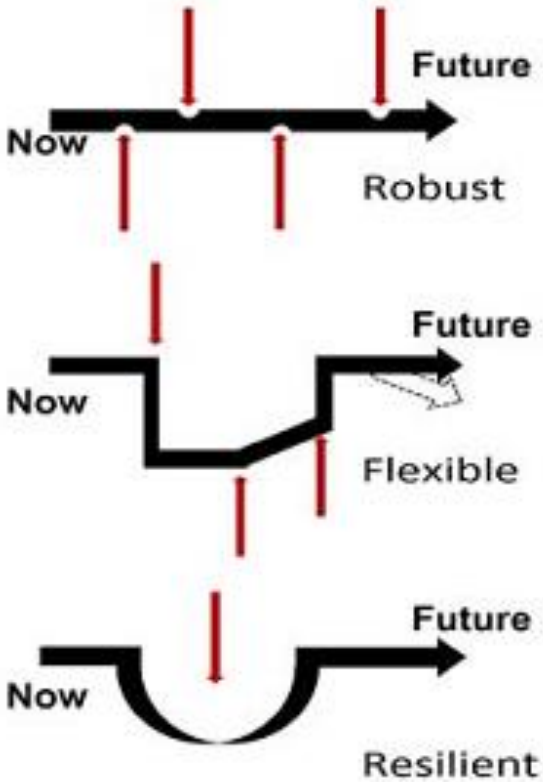


In an **unstable system**, a small disturbance can push the ball over a threshold



Conditional changes can make a system less resilient





Robust, Flexible or Agile and Resilient Behaviors. (Husdal, 2009)

- Robustness means the ability to stay on track and absorb unforeseen external events (forces)
- Flexible system does not ensure what might happen after unforeseen external events (disruptions)
- **Resilient system** regains a desired (original) path after the deviation

Resilience in Power Grids

- **Resilience in power grids is defined as a capability to cope with adversity arising from intentional and unintentional threats (forces), and to recover in a timely manner to an acceptable level (a new equilibrium) of performance after have been stressed.**

- **For electricity systems, shocks could come in various ways; in the form of physical shortages of fuel, global fuel price rises, the introduction of environmental regulation, physical shortages of imported electricity, and unplanned surges in demand.**

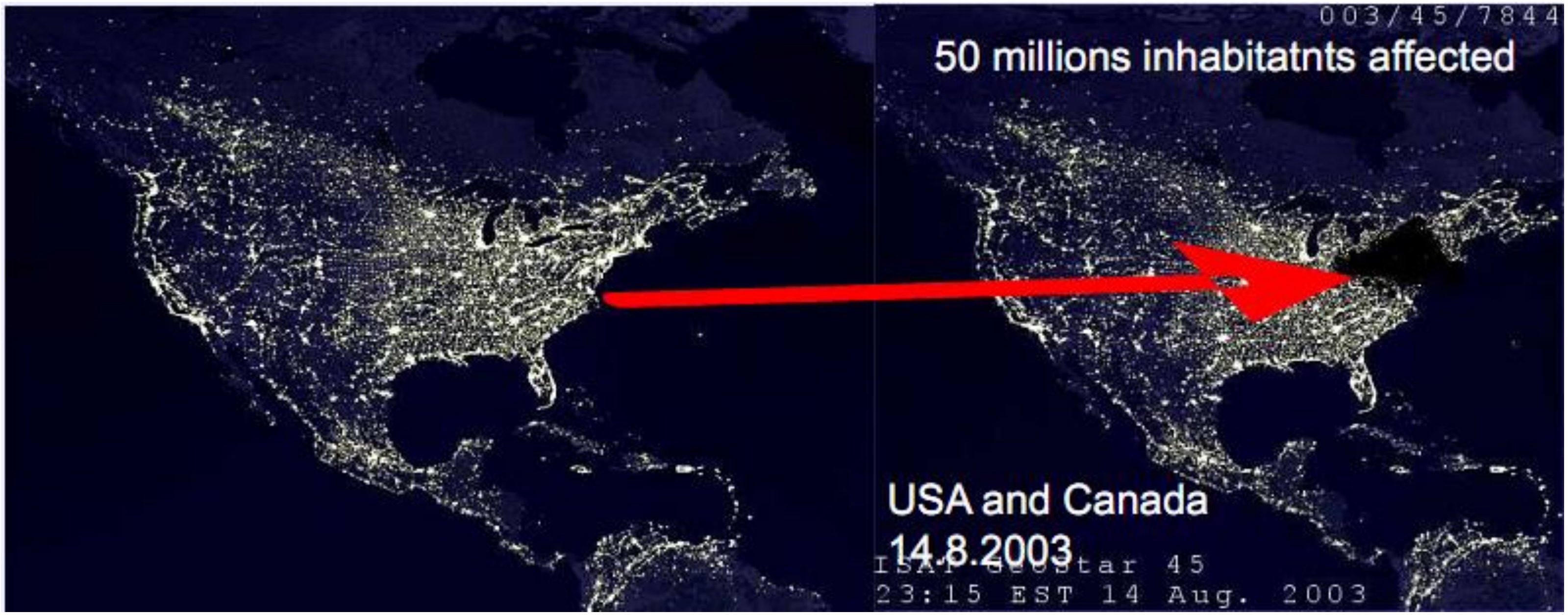
- **"Resilience is the ability to reduce the magnitude and/or duration of disruptive events." - Terry Boston, PJM President and CEO**

- **Resilience of electric grids is the "ability of a system to gradually degrade under increasing system stress, and then to return to its pre-disturbance condition when the disturbance is removed."**

Definition of Resiliency :

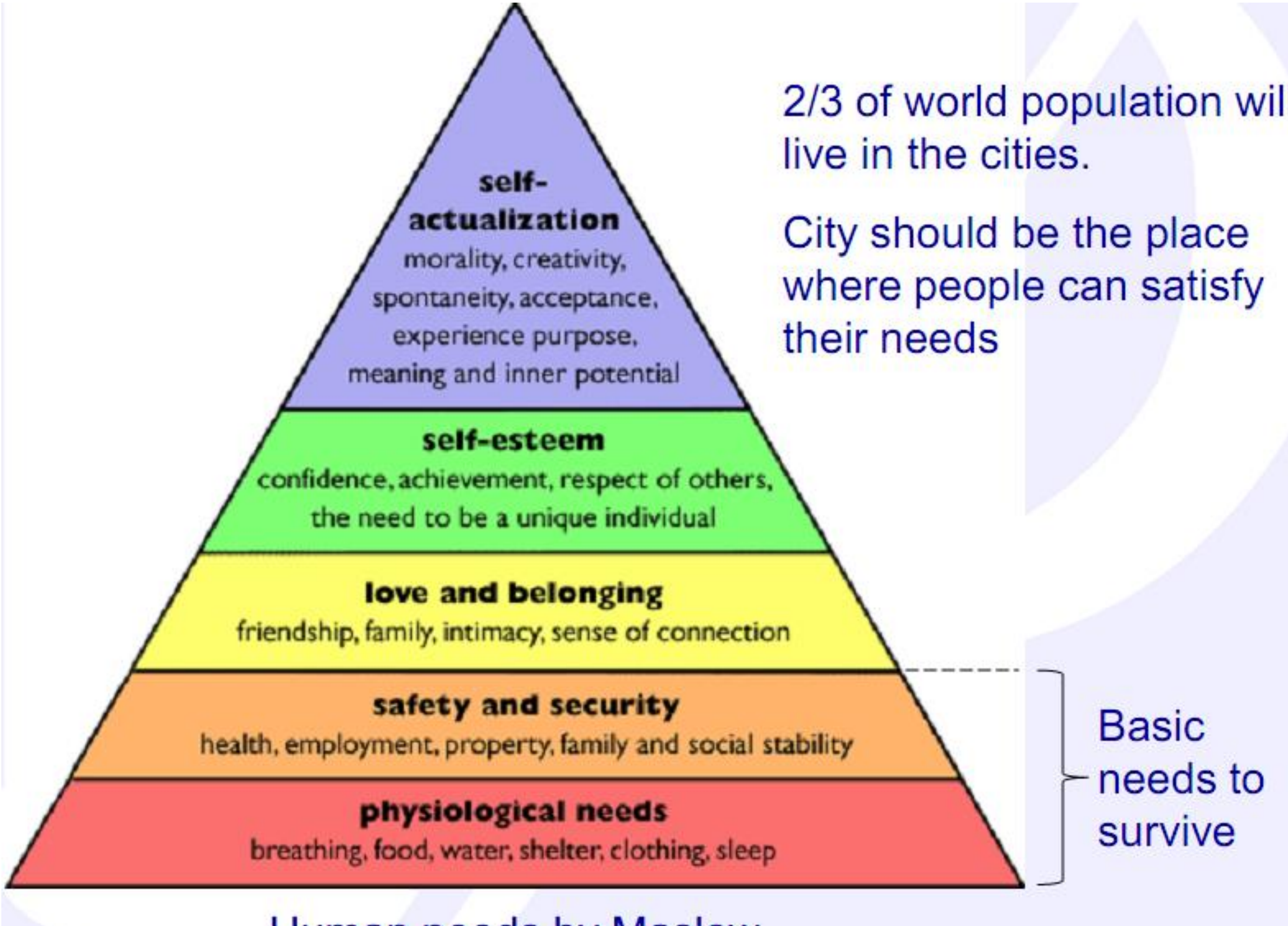
Resilience is the ability to absorb shocks, while retaining its function to return the original function after shocks removed.

- Jaeseok Choi, 2014


003/45/7844
50 millions inhabitatnts affected
USA and Canada
14.8.2003
23:15 EST 14 Aug. 2003

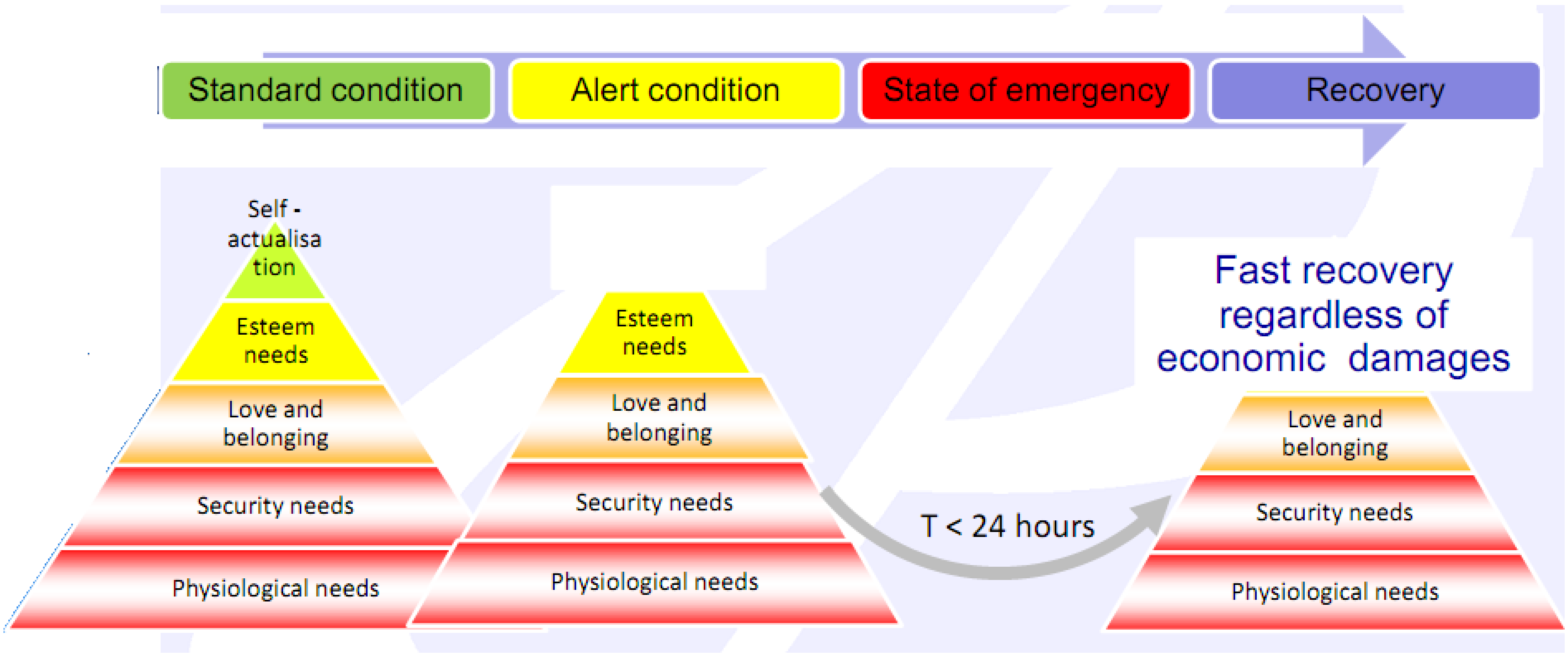

Company can lose control
over grid in 5 seconds
Italy 27.-28.9.2003
56 millions inhabitatnts affected

Holistic approach to resiliency is based on human safety



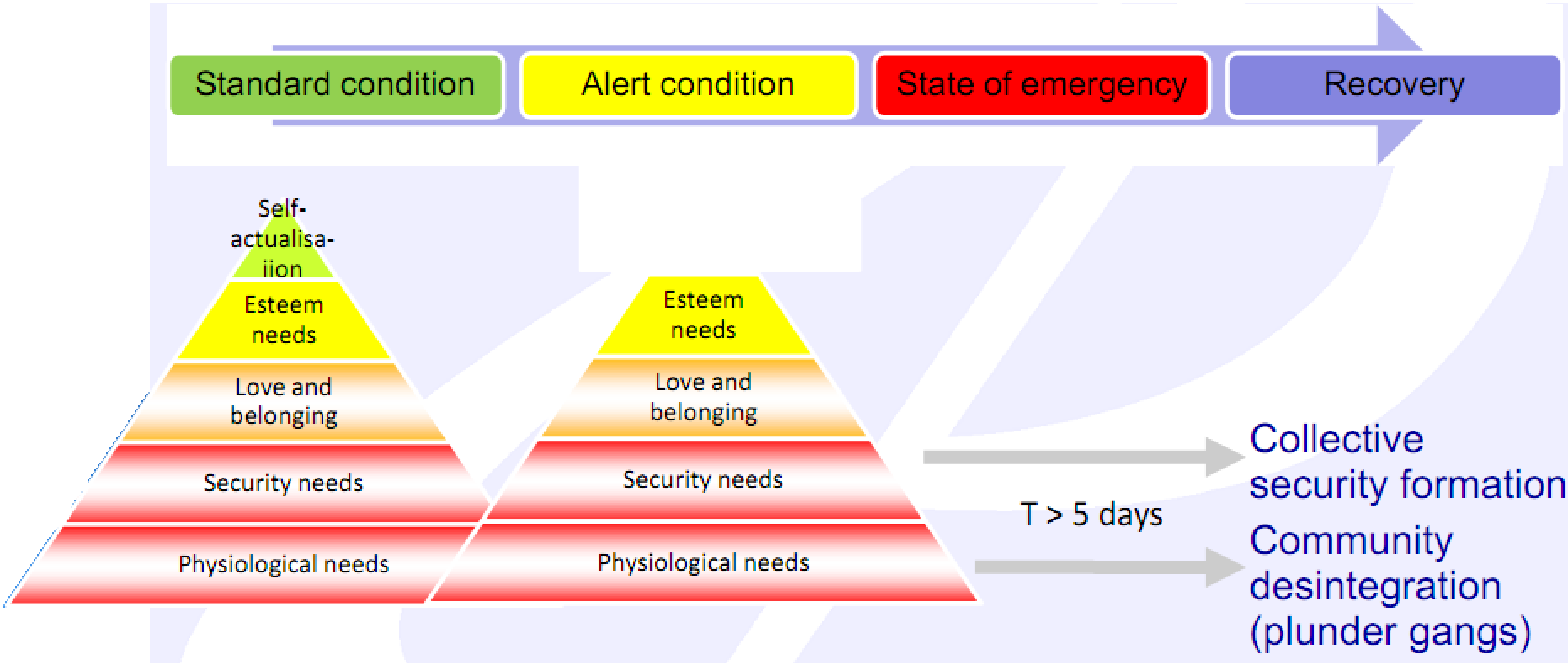
Human needs by Maslow

Vulnerability of society during short-term disaster



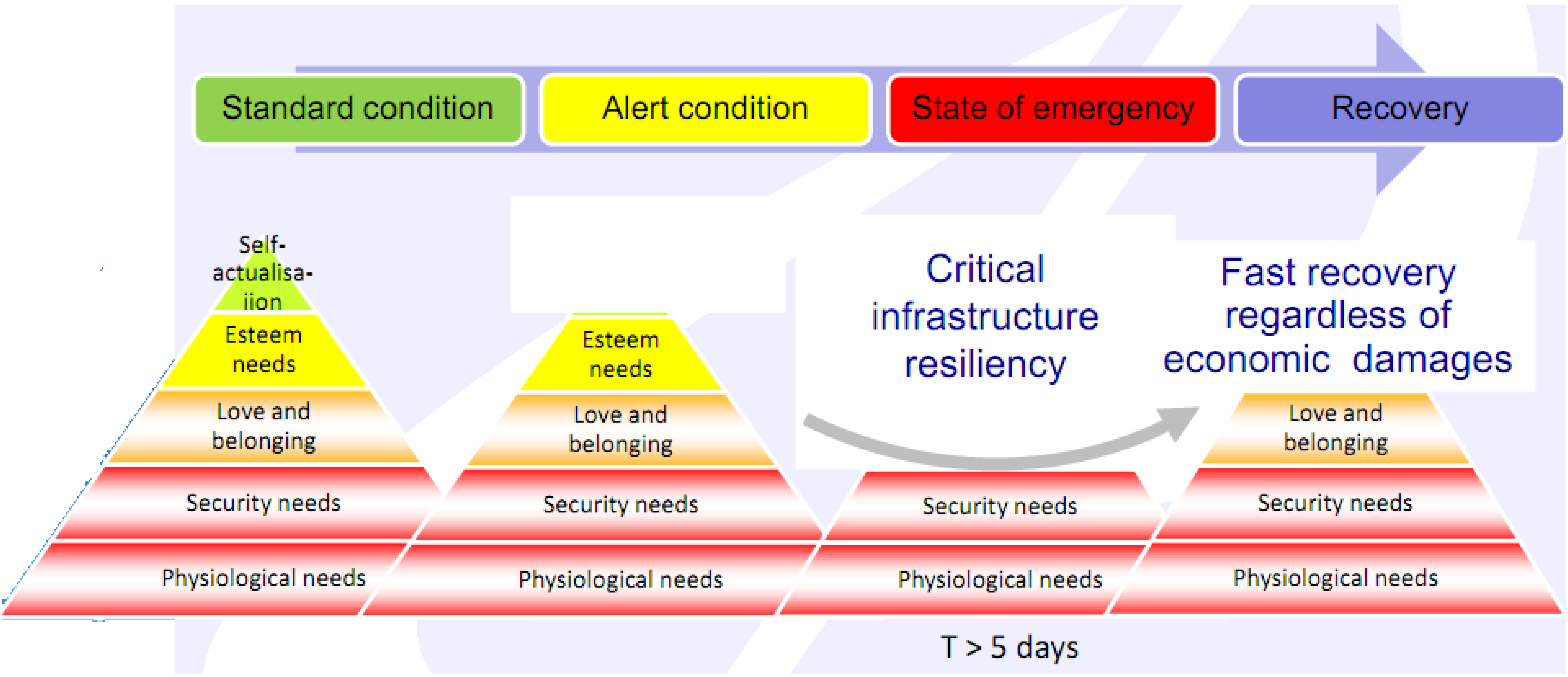
Blackouts: USA 2003, Italy 2003, …

Experience from vulnerability of society by long-term disaster



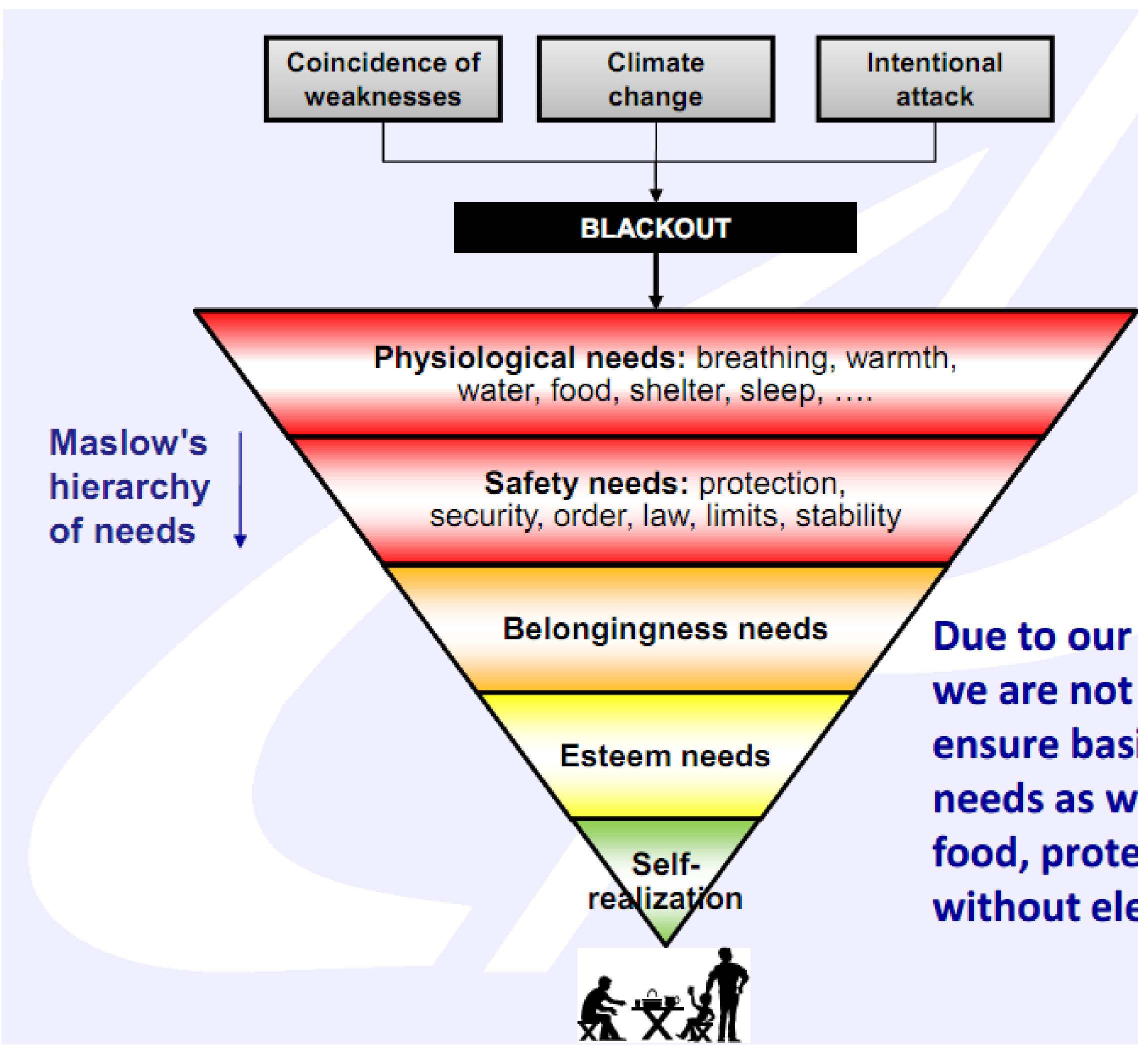
Experience: New Orleans (Katrina 2005), Haiti a Chile (earthquake 2010),…

Goal of critical infrastructure resiliency: preservation of basic needs in all cases



Human settlements has changed to open metropolises. Open, unable survive long-lasting cut-off from infrastructure

Blackout is “Sword of Damocles” over our civilization



Due to our dependency we are not able to ensure basic human needs as warmth, drink, food, protection, … without electricity

III. HOW and What are Survival Energy DNAs?

Survival Conditions of Energy DNA
(Survival Energy DNA Guide Lines)

生存(Survival) of Energy DNA

1. **Clean? : YES -> Survival**
2. **Certification of Human Survival? : YES -> Survival**

淘汰 (Exclusion, Selection for Rejection)

1. Dirty? : 미세먼지발생, 환경오염발생 인자를 가지는가?
2. 기상이변(Example: CO_2) 을 발생하는 요인을 지니고 있는가?: 지구온난화 요인
3. 人類의 生存을 威脅하는가(Nothing for Resiliency)?

   - Example: 체르노빌 원자력사고, 후쿠시마 원자력사고

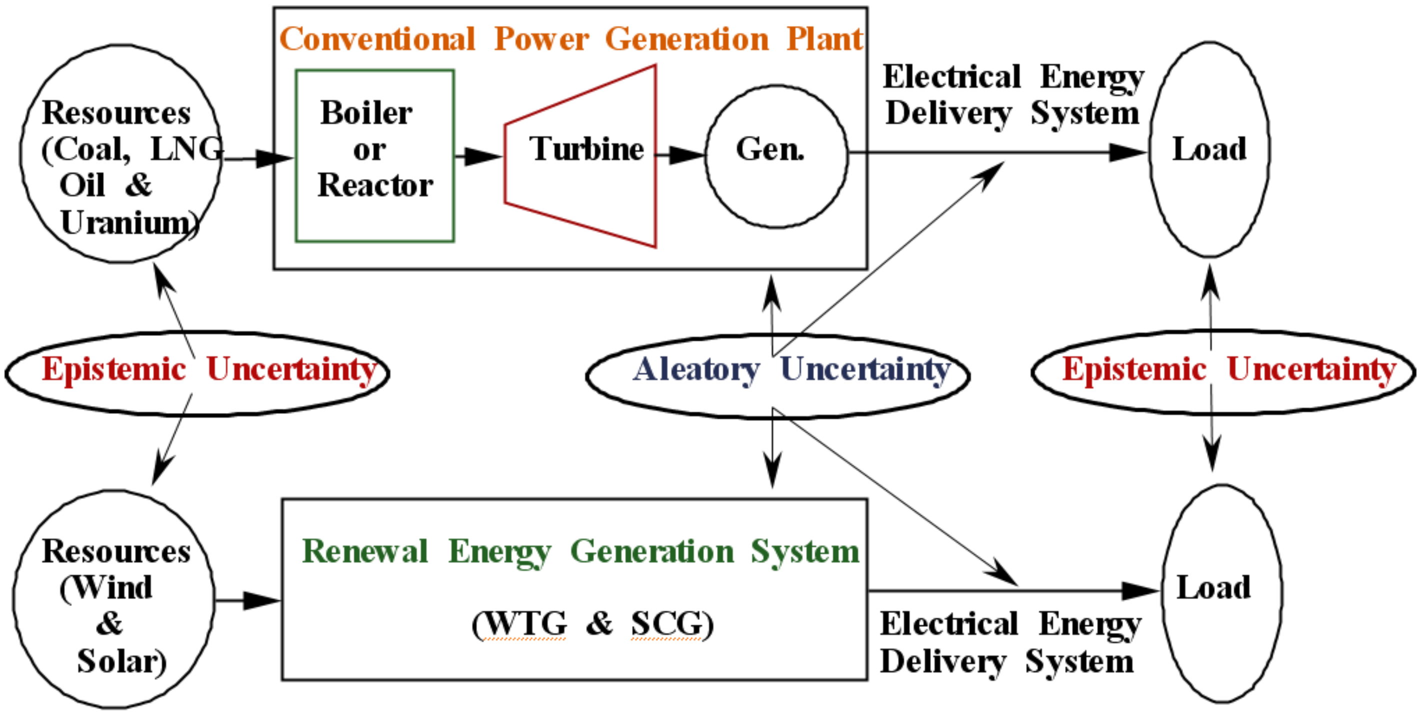
임진왜란: 활과 화승총
누가 진화에서 우세한 DNA인가?

IV. Flexibility Sources for Solution of REG Problems

- Uncertainty of Resource Supply
- Intermittent Generation
- Low Capacity Factor - Economics
- Massive Area for REG Plant Construction
- Difficult Grid Connection ……
- Solution -> Higher Flexibility!

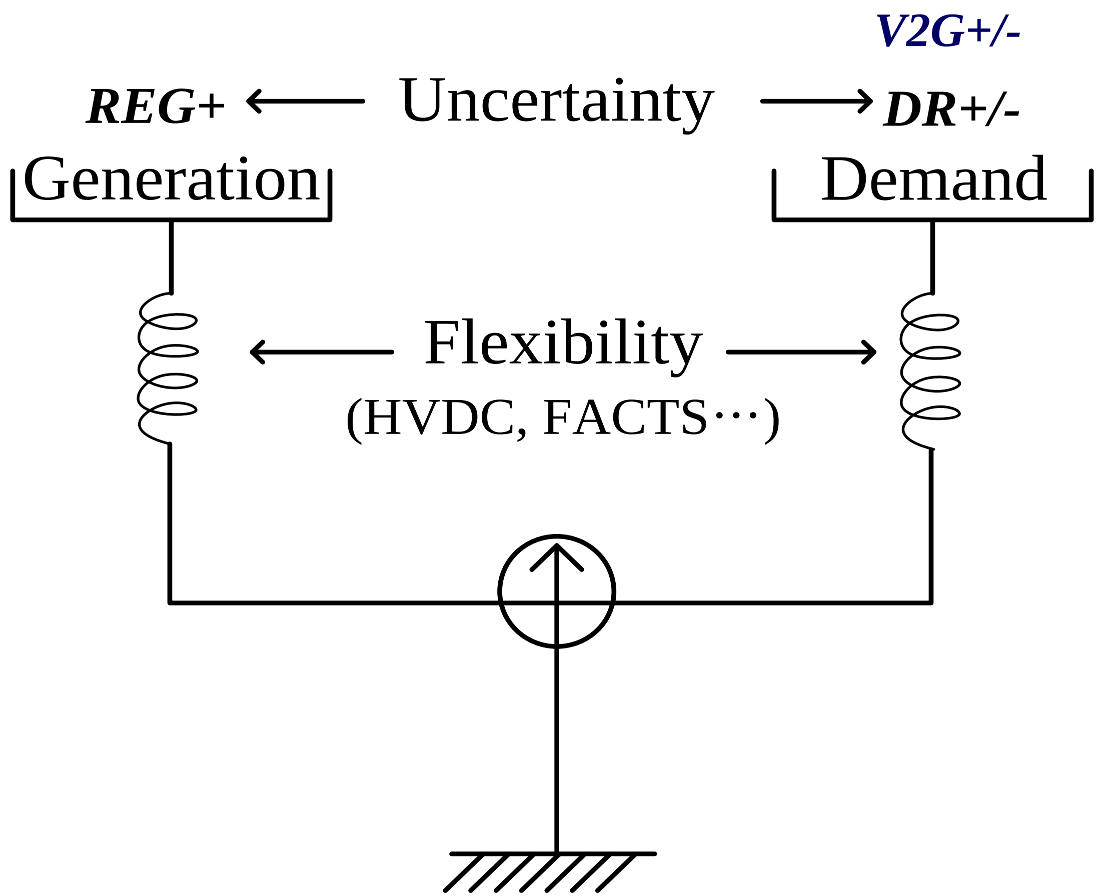
What is the kind of uncertainties in power system in REG?

- Aleatory uncertainty: Outage of Unit (Ex, Outage of Generator, Lines..)
- Epistemic uncertainty: Uncertainty of Information
  (Ex, Forecast of Load, Supply of Resources)*



* Roy Billinton and Dange Huang, "Aleatory and Epistemic Uncertainty Considerations in Power System Reliability Evaluation", PMAPS, May 25-29, 2008.

What is the relationship between uncertainties and flexibility in the new future power system?



Analytic Frameworks to Measure Flexibility

A simple summary of major sources of flexibility, such as capacity levels of dispatchable plants, pumped-hydro storage, demand response, and interconnection to neighboring systems, can provide a snapshot of system flexibility.

One example of this framework is the “flexibility chart” in Figure.

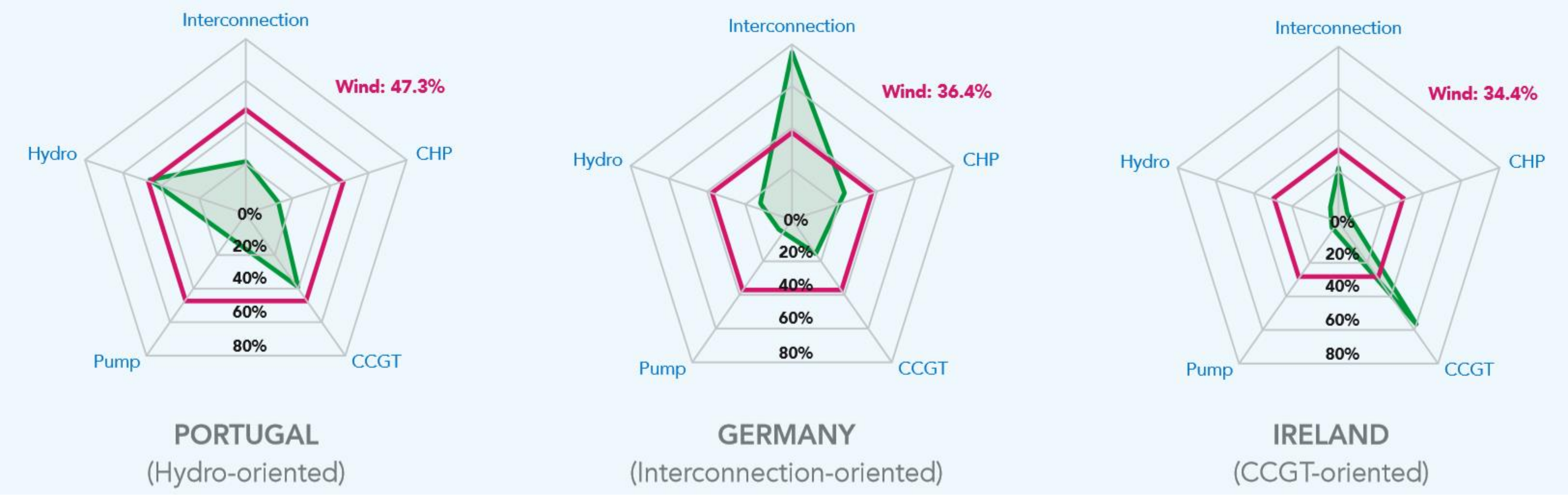


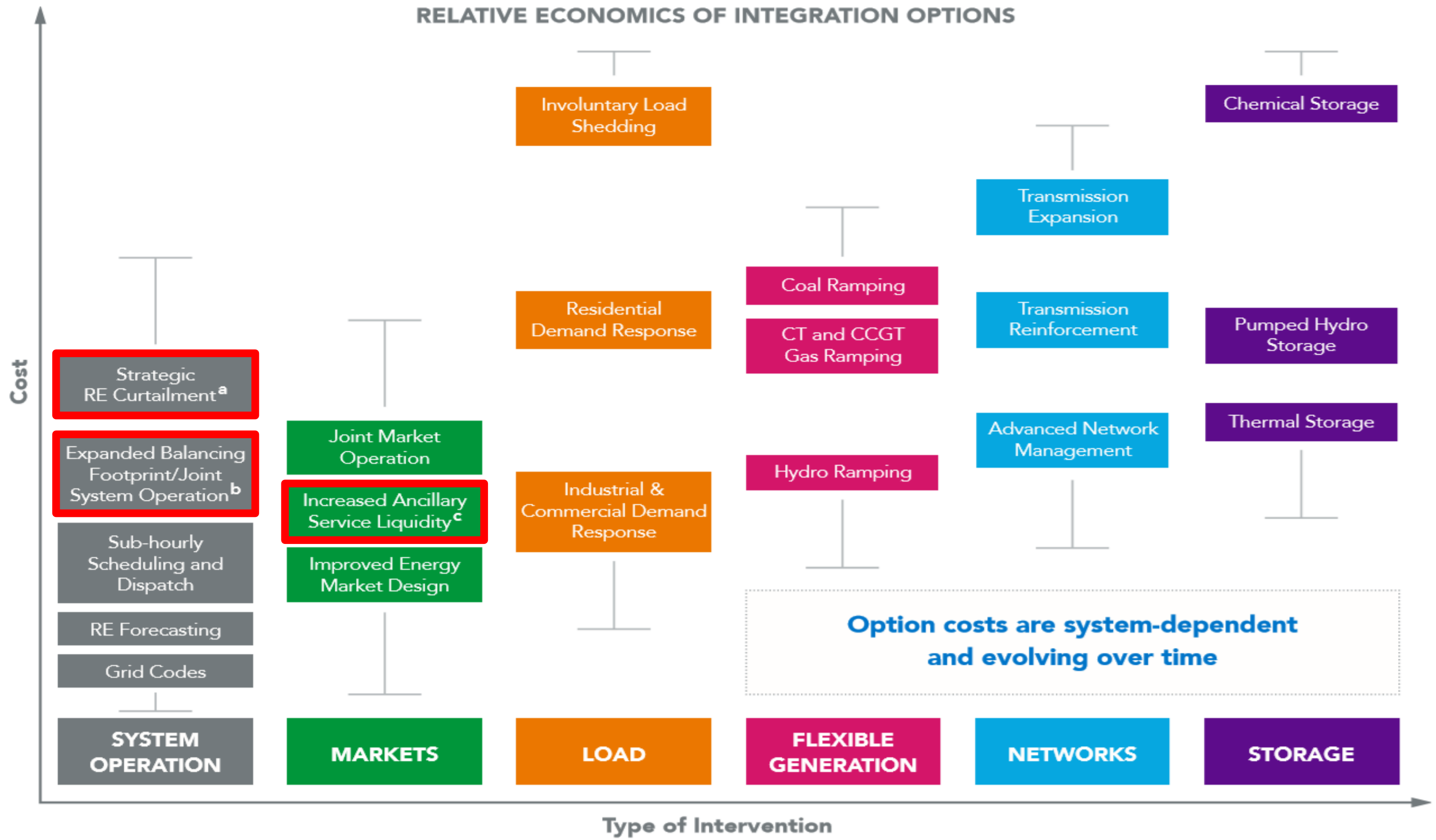
FIGURE. Frameworks and metrics for measuring power system flexibility are evolving. These flexibility charts, developed by Yasuda et al., provide a snapshot overview of what types of generation-based flexibility each country has, and the maximum share of wind power (red text) during one hour relative to demand. The charts show in green the percentage of installed capacity of each potential source of flexibility relative to peak demand, i.e., high installed capacity translates to a possible source of flexibility. However, since capacity does not map directly to flexibilty, the size of the green area relative to red does not have a direct meaning. Instead, the charts only highlight potential flexibility sources.

ANALYTIC FRAMEWORKS TO MEASURE FLEXIBILITY

Minimal | Moderate | Significant

	GETTING STARTED	GETTING SERIOUS	GETTING VERY SERIOUS
Purpose	Simplified communication tool Comparison across jurisdictions	Screening tools to evaluate need for further flexibility analysis	Flexibility-adapted resource planning
Complexity of Execution	Simple analytical framework	Required data may not exist Data curation and tool customization may be required	Requires advanced analysis techniques and data requirements
Example Data Requirements	Existing capacity of power system Capacity mix and availability of interconnect systems	Renewable resource assessments Various time series data sets Ramping capabilities of dispatchable units	Comprehensive suite of power system data Operational rules and market and policy context
Limitations on Execution	Existing capacity and interconnection data is generally available in all jurisdictions	May be infeasible if renewable resource assessments are unavailable	May be infeasible without significant data and modeling and analytical expertise
Limitations on Results	Does not evaluate whether system is sufficiently flexible May exclude aspects of flexibility that cannot be reduced to capacity Ramping capabilities of individual generators not considered	Simplified treatment of dispatchable generators Presumes fully built-out transmission	While analysis results are always qualified, this tier of tools and metrics provide the most robust of those outlined in this paper
Usefulness of Tool Relative to Generation and Load Variability	Preliminary and comparative analyses	Systems which are evaluating need for more robust flexibility assessment (e.g., generation levels of 5-15% wind or solar)	Systems which already utilize all 'no-regrets' sources of flexibility
Metric	Flexibility Charts (Figure 2) GIVAR III visual (Figure 3)	FAST2 (Figure 4)	Insufficient Ramping Resource Expectation (IRRE) (Figure 6) Bulk System Flexibility Index (BuSFI)[14]

How Can Policymakers and Regulators Help Increase Flexibility?



a. There is a tradeoff between costs of flexibility and benefits of reduced (or no) curtailment, hence a certain level of curtailment may be a sign that the system has an economically optimal amount of flexibility.

b. Joint system operation typically involves a level of reserve sharing and dispatch co-optimization but stops short of joint market operation or a formal system merger.

c. Wind power can increase the liquidity of ancillary services and provide generation-side flexibility. Curtailed energy is also used to provide frequency response in many systems, for example Xcel Energy, EirGrid, Energinet.dk.

Key messages for policymakers as to power system flexibility

- Power systems are already flexible, designed to accommodate variable and uncertain load.
- In different power systems, sufficient flexibility exists to integrate additional variability, but this flexibility may not be fully accessible without changes to power system operations or other institutional factors.
- In sufficient quantities, renewable energy will change the shape of dispatch requirements so that system flexibility must be reassessed, and thus growth in the levels of renewable energy may require increasing levels of flexibility.
- A wide range of power system elements impact system flexibility, ranging from transmission assets to generation characteristics and operational practices.
- While there are many emerging flexibility metrics and assessment methods, there is no standard metric for measuring flexibility to date, and metrics continue to evolve (change).
- Policy incentives can be designed to anticipate flexibility needs and support system flexibility.

- There are several approaches to improving grid flexibility, including improving ramping capabilities of the dispatchable generation fleet, increasing demand-side and distributionlevel participation, and increasing coordination across multiple markets or balancing areas.

- Finding the optimal investment level requires consideration not only of short-term operational requirements, but longterm viability to recover costs. Uncertainty regarding the level, timing, and type of renewable energy deployment will complicate the problem of finding the optimal levels of investments.

- Based on investment needs independent of variable renewable energy and smart grids, power systems in developed and emerging economies may take very different paths to increasing flexibility.

- Flexibility considerations can be integrated into the design of procurement policies for new renewable energy generation (e.g., feed-in tariffs, subsidies), for example, by basing support on location of generation, provision of frequency support, alignment with demand, and/or integration into dispatch optimization.

SOURCES OF FLEXIBILITY

System operations and markets. Changes to system operation practices and markets can unlock significant flexibility, often at lower economic costs than options that require changes to the physical power system.

Flexible demand and storage. Demand- side management and demand response enable consumers to participate in load control based on price signals. Demand response mechanisms include automated load control by the system operator; smart grid and smart metering; real-time pricing; and time-of-use tariffs. Demand response can be relatively inexpensive but requires strict regulations related to response time, minimum magnitude, reliability, and verifiability of demand-side resources.

Storage technologies—including pumped hydro and thermal storage and batteries—hold energy produced during periods of excess VRE generation and then discharge this energy when it is needed. Relative to demand response and other options for flexibility, storage generally has a higher capital cost.

Flexible generation. Conventional power plants and dispatchable renewable generators such as biomass or geothermal plants provide flexibility if they have the ability to ramp up rapidly and ramp down output to follow net load; quick shut down and start up; and operate efficiently at a lower minimum level during high VRE output periods. New and retrofitted large-scale power plants, as well as smaller- scale distributed generation (e.g., micro combined heat and power units), can supply flexible generation.

Flexible transmission networks. Extending transmission lines and interconnecting with neighboring networks provide the power system with greater access to a range of balancing resources. The aggregation of generation assets through interconnection improves flexibility and reduces net variability across the power system. Other sources with flexibility include smart network technologies and advanced network management practices that minimize bottlenecks and optimize transmission usage.

V. HESS Example: Variable Speed and Ternary P-G Units to Mitigate Wind and Solar Intermittent Production

http://powervision-eng.ch/Profile/Publications/pdf/Hydrovision_2014.pdf

powervision-eng.ch

a share of 55% of the electricity generation by renewable energies by 2020, are also planning and developing large conventional and pumped storage capacities [18].

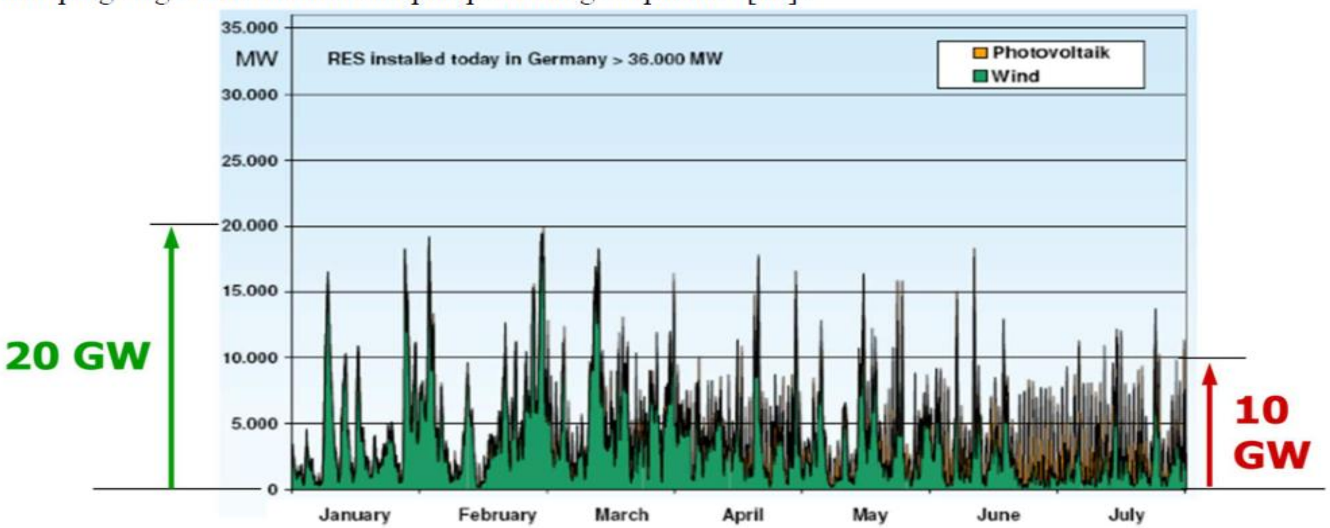
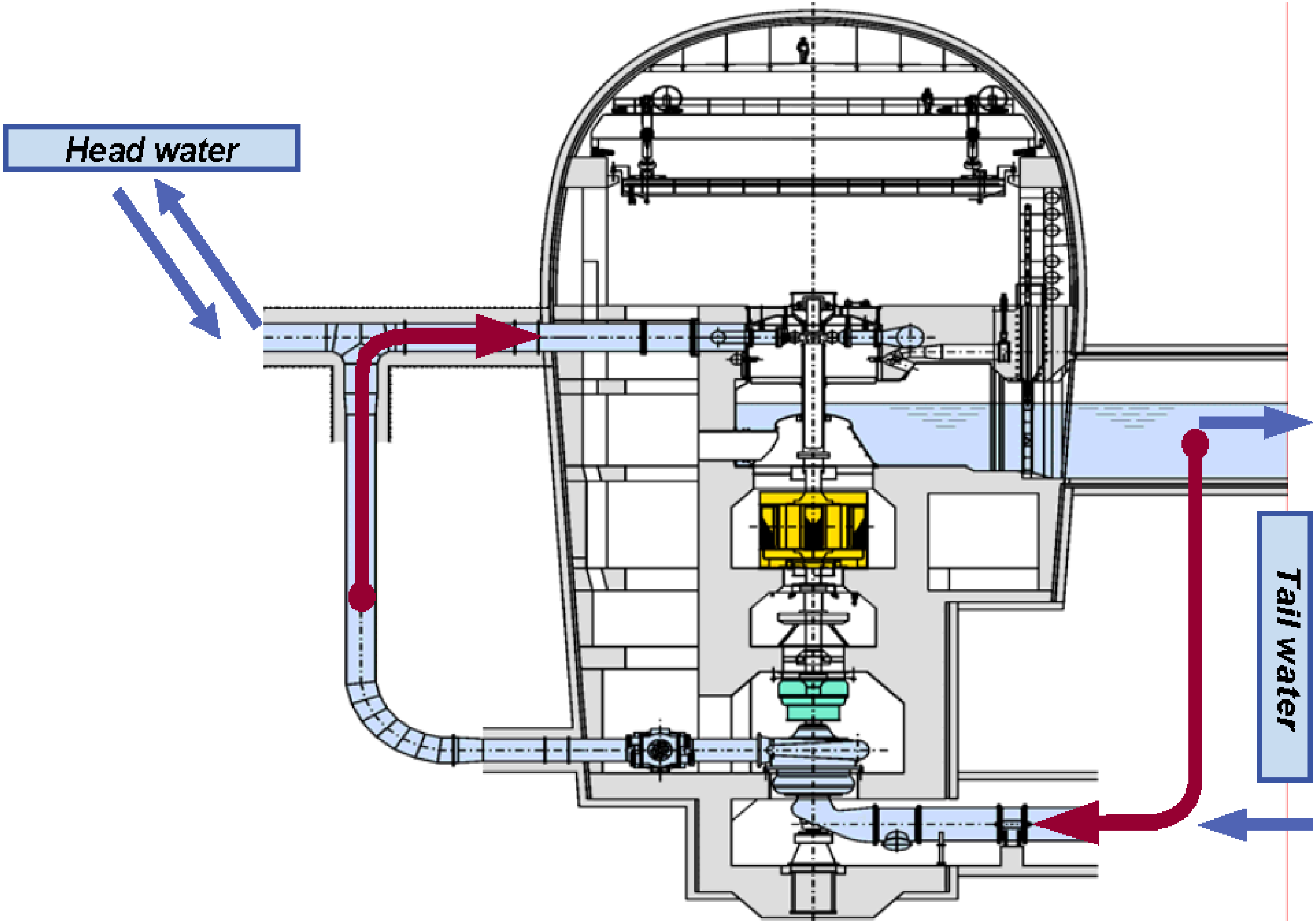
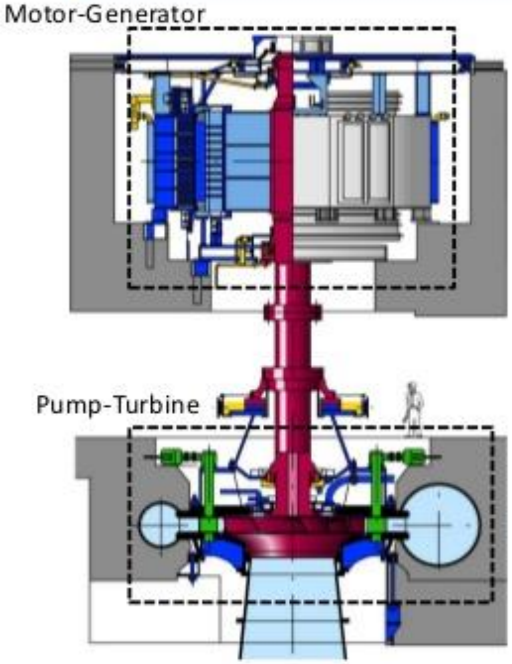


Figure 1 Wind and solar electricity generation in Germany in 2010 (adapted from: "A Comparison of Advanced Pumped Storage Equipment Drivers in the US and Europe" by R. K. Fisher et al., Hydrovision 2012, Louisville, USA.[7]).

Beside storage and substitution production capabilities, pumped storage power plants can also significantly improve the power network stability due to their production flexibility and ancillary services capabilities. However, the planning, design and optimization of new pumped storage power plant developed to compensate renewable energy volatility requires detailed analysis of the power network stability. In this context, advanced simulation models of each energy conversion power station are necessary to investigate the power network dynamic behavior and address the power network stability for various configurations and scenarios. This problematic is addressed in the present paper through the modeling, numerical simulations and analysis of the stability of a representative islanded


Head water
Tail water

Pumped Storage Power Plant



Goldisthal PSPP Generator and Turbine

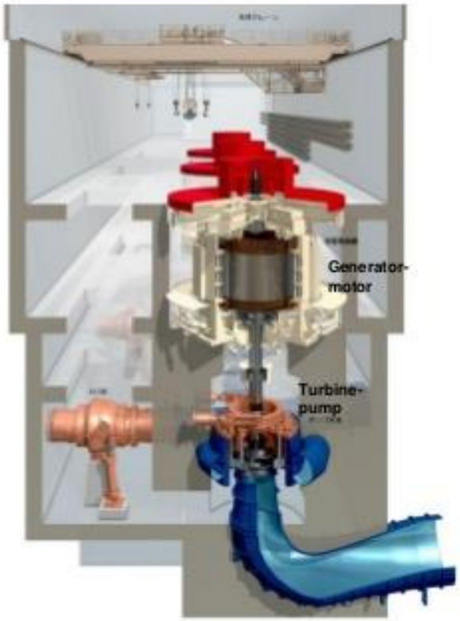
During power generation the water from upper reservoir flows and turn turbine counter clockwise (for this case).

Generator and Turbine for PSPP are same with the conventional HPP. When pumping, the generator acts as motor, consuming power from grid. Motor turns the turbine to opposite direction.

To start the motor, it is necessary to use motor starting device as Static Frequency Converter or Cycloconverter, and change the phase sequence from U-V-W to U-W-V.

Before pumping begins, water in spiral case should be drained, and filled with water after rated speed has been achieved.

Adjustable Speed Pumped Storage



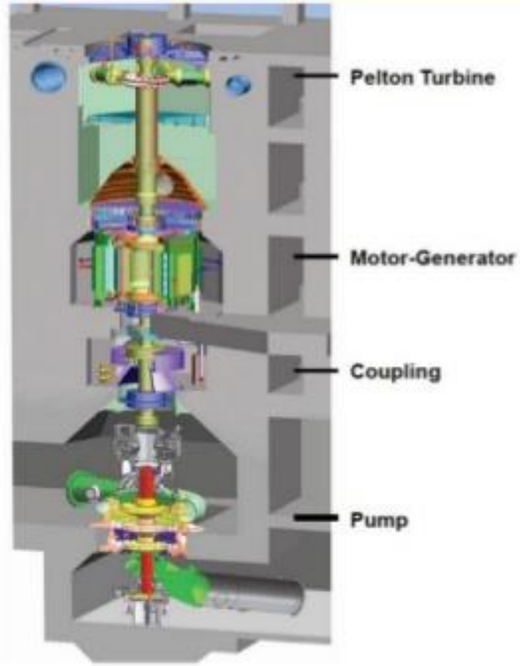
Kyogoku Adjustable Speed Pumped Storage Power Plant, Japan

This enables adjustment of power consumed during pumped mode and power output during generation mode, by adjusting the speed of turbine and generator.

The difference is in the generator. As you can see from left image, the rotor coils are similar to coils in stator. The excitation utilizes variable frequency AC excitation system, which is different from conventional generators.

The AC excitation enables compensation of the varying mechanical speed to synchronize with grid frequency.

Ternary Pumped Storage

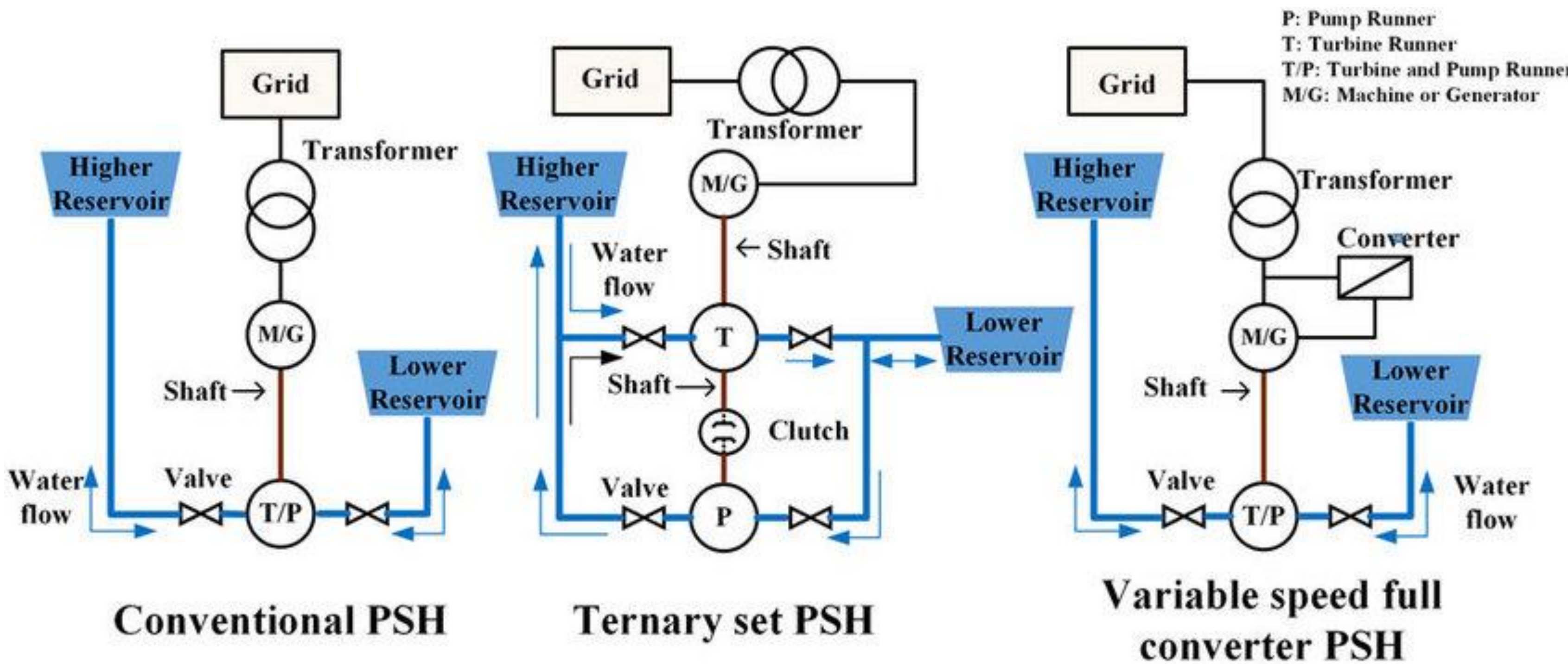


Cross section of Ternary Pumped Storage Power Plant

This power plant combines Pelton as turbine and Francis as pump. The net output of plant is the power generated from Pelton minus power consumed by Francis.

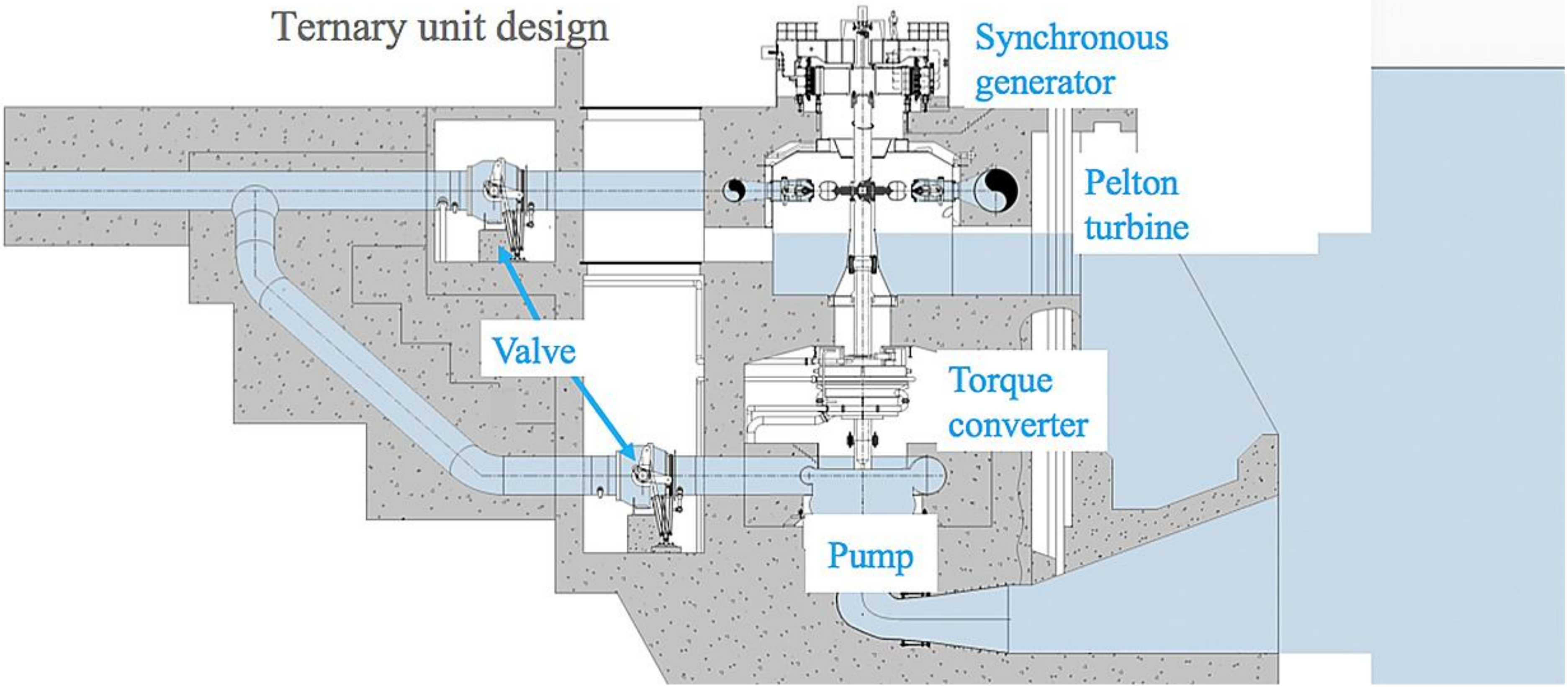
By this power plant, the power electronics for variable frequency AC excitation system and motor starter are no longer necessary. Thus, eliminates additional harmonic voltage or current source in the grid.

Coupling to Francis pump can be swiftly engaged and disengaged. This enables shorter transition between power consumption mode and power generation mode, as reversing the turbine rotation is not necessary. Very suitable to response to fluctuating power supply from wind turbines.



Downloading the **Figure** from "Modeling and Simulation of Ternary Pumped Storage Hydropower for Power System Studies".

Ternary unit design



these two technologies compared to a classical reversible Francis pump-turbine are summarized in Table 1.

During the selection process, if most of technical aspects can be reasonably evaluated, aspects related to system stability, regulating services and other ancillary benefits are more difficult to address. Moreover, Transmission System Operators, TSO, require demonstrating the capability of new units to withstand typical power network faults and to comply with Grid Codes. In this context, time domain simulation of the dynamic behavior of the full pumped storage power plant including hydraulic circuit, electrical installations, control system and power network provide very useful insights for decision making.

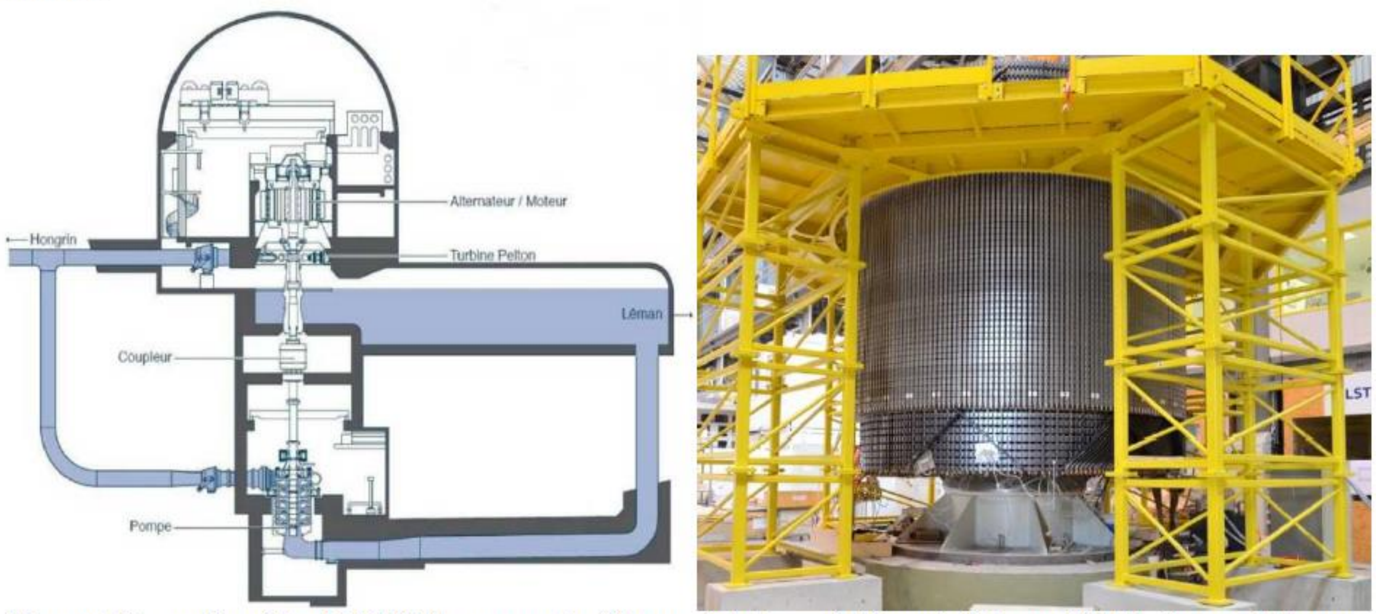
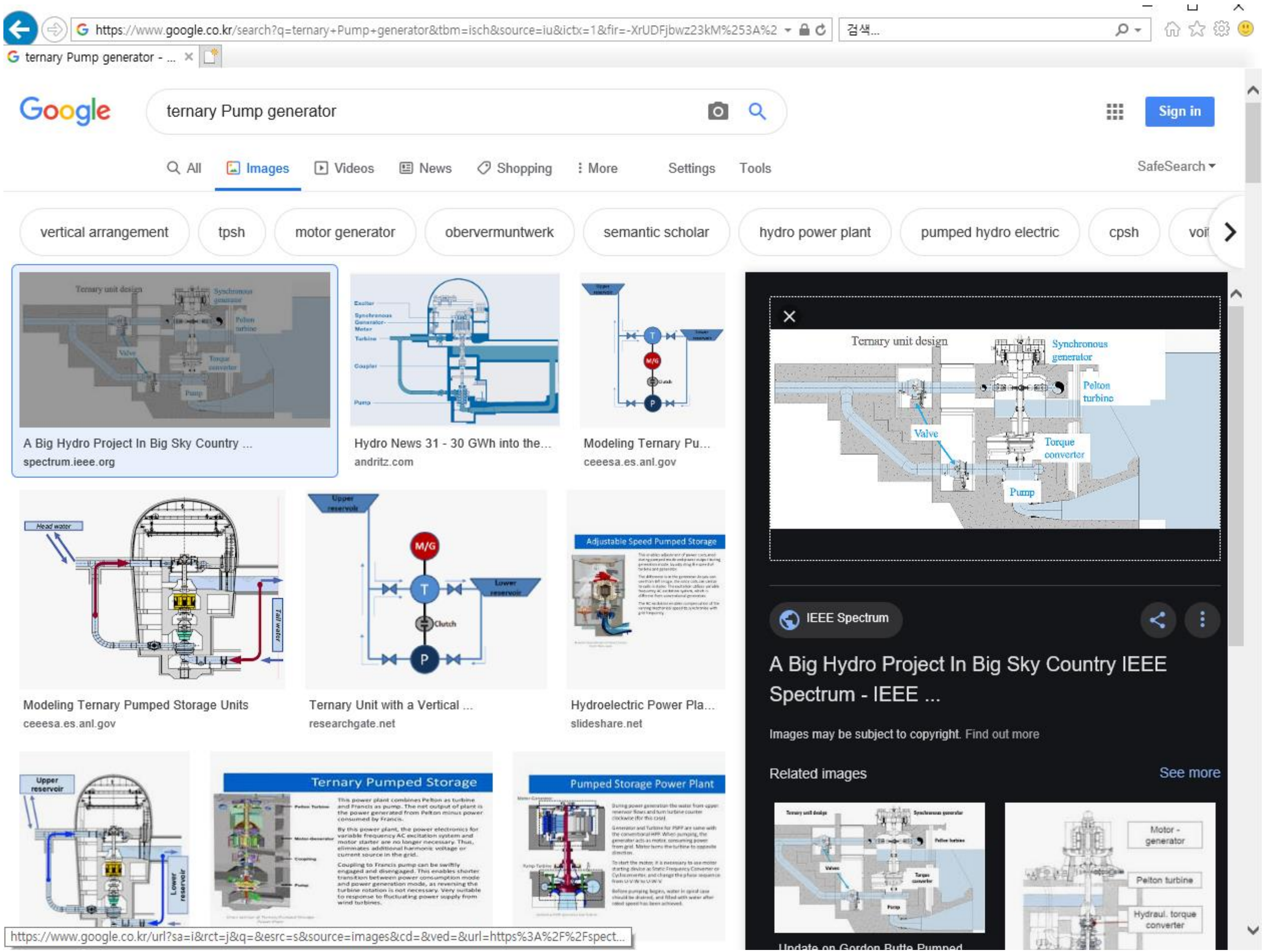


Figure 3 Example of 2 x 120 MW ternary unit of Forces Motrices de Hongrin Léman, FMHL, Pumped Storage power plant in Switzerland [10] (left), and rotor of the doubly fed induction machine motor-generator for 4 x 250 MW Linthal Pumped Storage Project in Switzerland on the right [28].



https://www.google.co.kr/search?q=ternary+Pump+generator&tbm=isch&source=iu&ictx=1&fir=-XrUDFjbwz23kM%253A%2
검색...
ternary Pump generator - ...
Google
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Sign in
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Images
Videos
News
Shopping
More
Settings
Tools
SafeSearch
vertical arrangement
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motor generator
obervermuntwerk
semantic scholar
hydro power plant
pumped hydro electric
cpsh
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Ternary Pumped Storage
Pumped Storage Power Plant
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Pump
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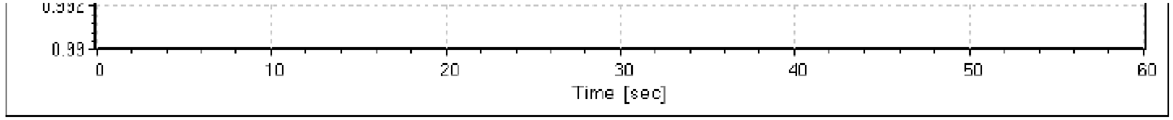


Figure 13 Comparison of the power network frequency resulting from photovoltaic power plant output power sudden variations of 50MW obtained with Ternary Unit and Variable Speed Unit.

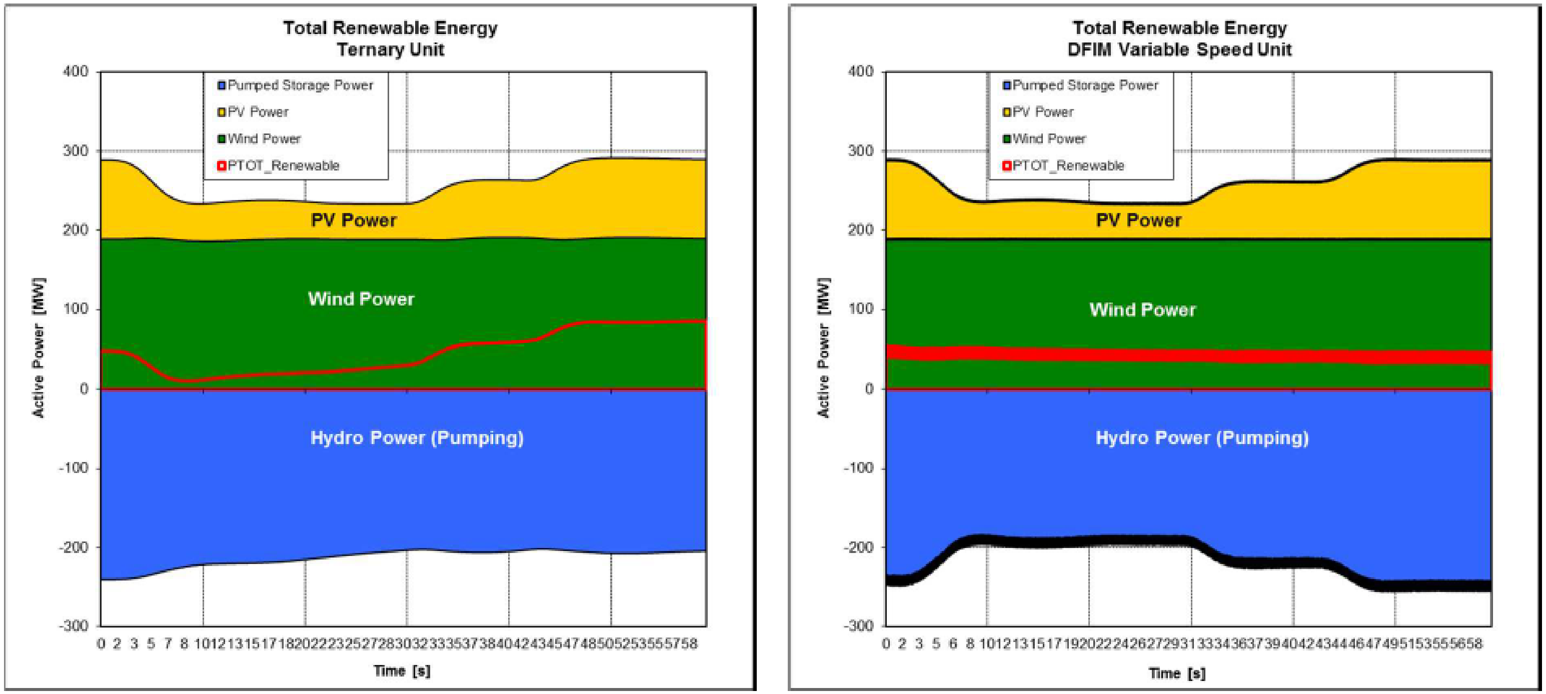
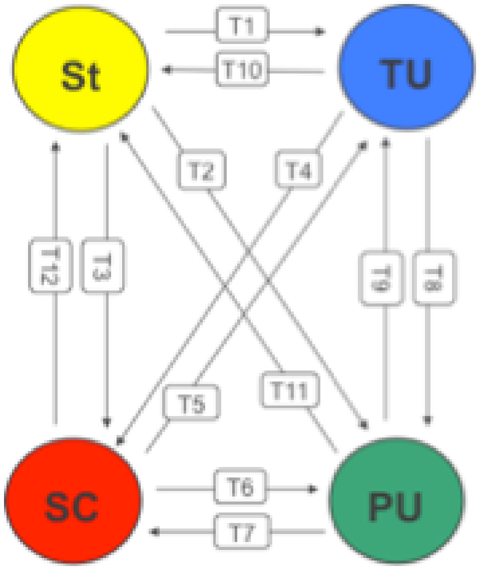


Figure 14 Comparison of the different renewable energy sources active power during photovoltaic power plant output power sudden variations of 50MW obtained with Ternary Unit (left) and Variable Speed Unit (right).

8.3. Wind power fluctuations

Figure 15 presents the time evolution of wind velocity around a mean value of 14 m/s considered for this second scenario, while the solar irradiation is considered constant at the value of 1'000 W/m^2. Figure 16 shows the corresponding wind power fluctuations and the resulting pumped storage input power variations. The frequency deviations obtained with ternary unit and variable speed unit are compared in Figure 17 pointing out frequency deviations reduced by a factor 5 with the variable speed unit compared to those obtained with the ternary unit.

Mode Change Times for Various Advanced Pumped Storage Technologies

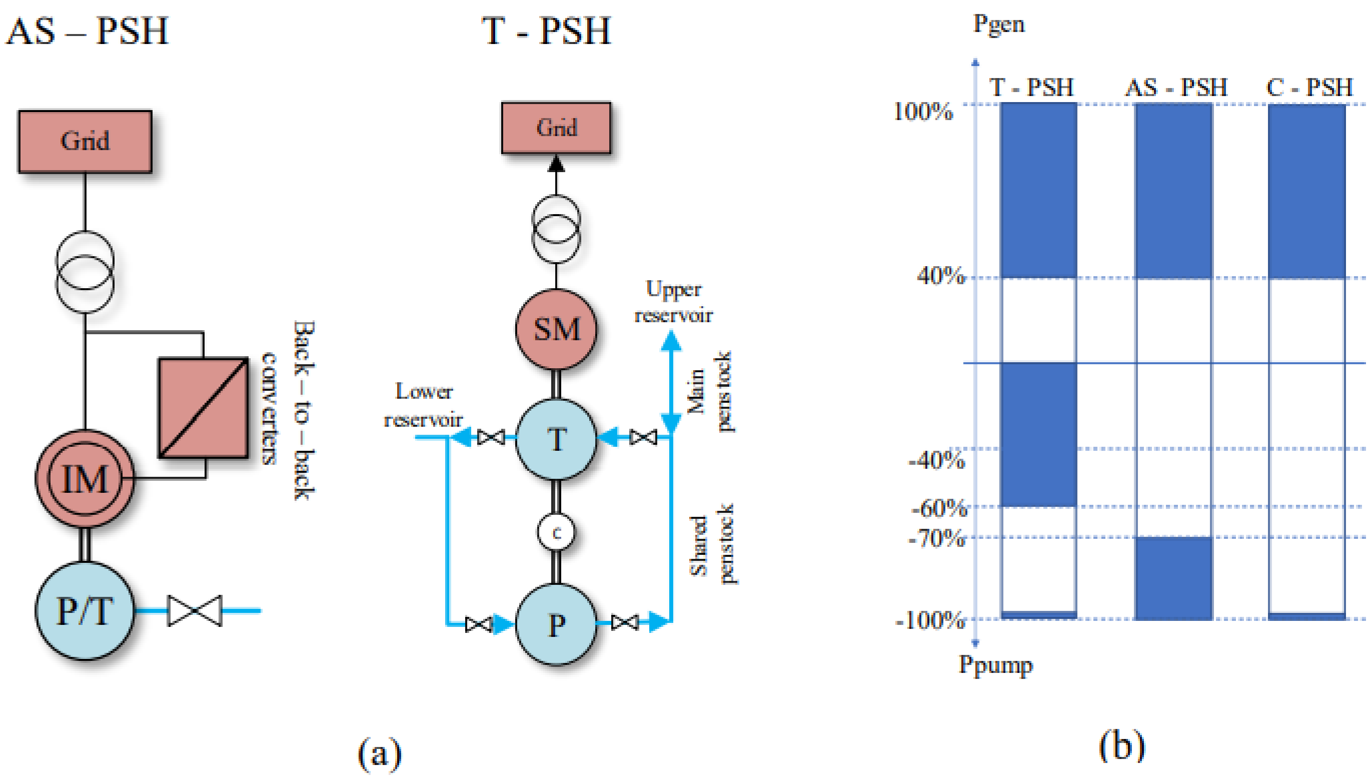


Pump Turbine			time [seconds]				
T	Mode change		A	B	C	D	E
1	Standstill →	TU-Mode	90	75	90	90	65
2	Standstill →	PU-Mode	340	160	230	85	80
5	SC-Mode →	TU-Mode	70	20	60	40	20
6	SC-Mode →	PU-Mode	70	50	70	30	25
8	TU-Mode →	PU-Mode	420	240	470	45	25
9	PU-Mode →	TU-Mode	190	90	280	60	25

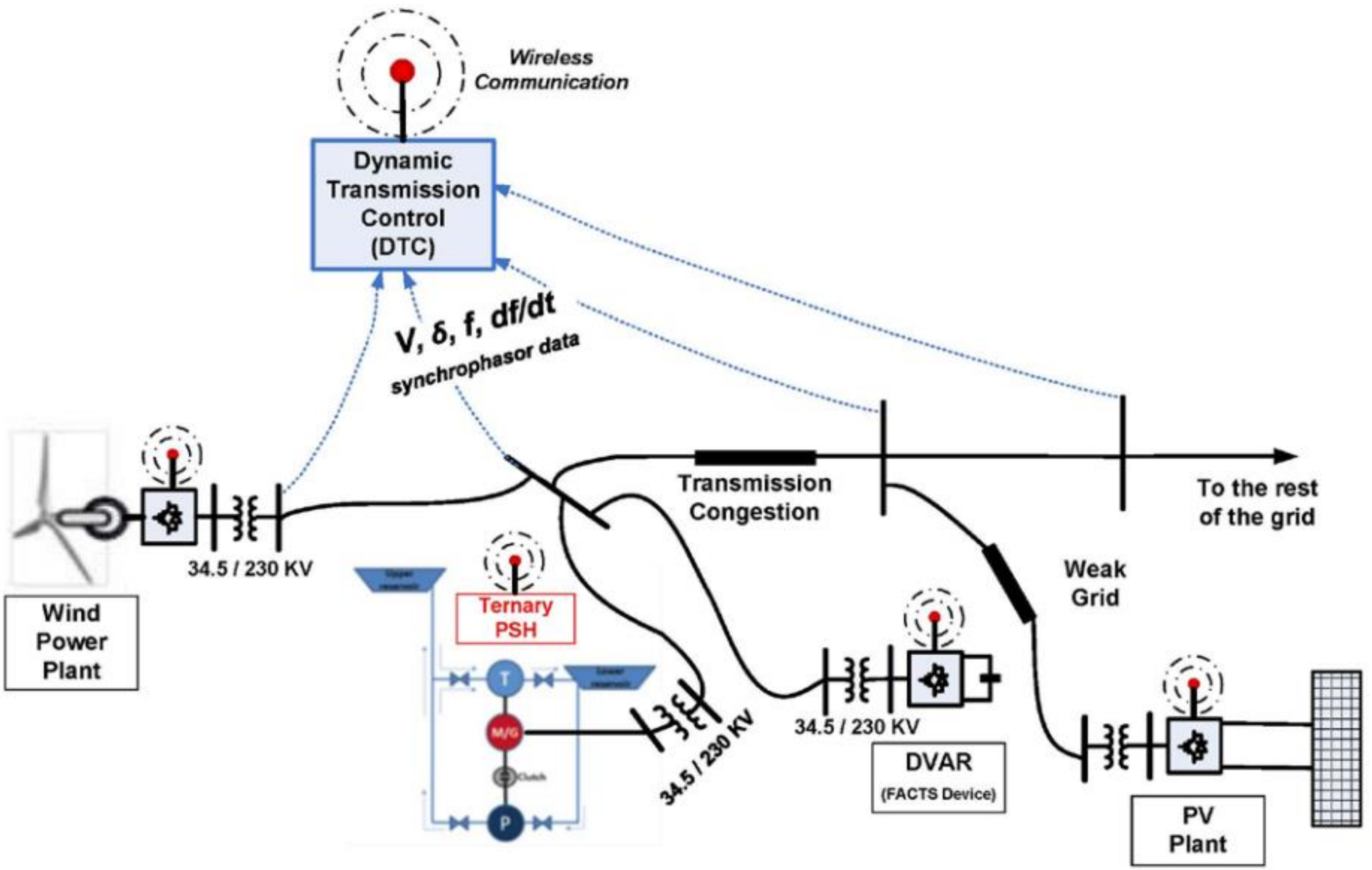
Reversible PT
A – advanced conventional (2012)
B – extra fast response conventional
C – VarSpeed, DFIM

Ternary set
D – with hydraulic torque converter + hydr. short circuit, horiz, with Francis Turbine
E – same as E but vertical with Pelton Turbine

TU = Turbine, PU = Pump, SC = Synchronous Condenser
Source: Reference 6, Fisher et al. (2012)

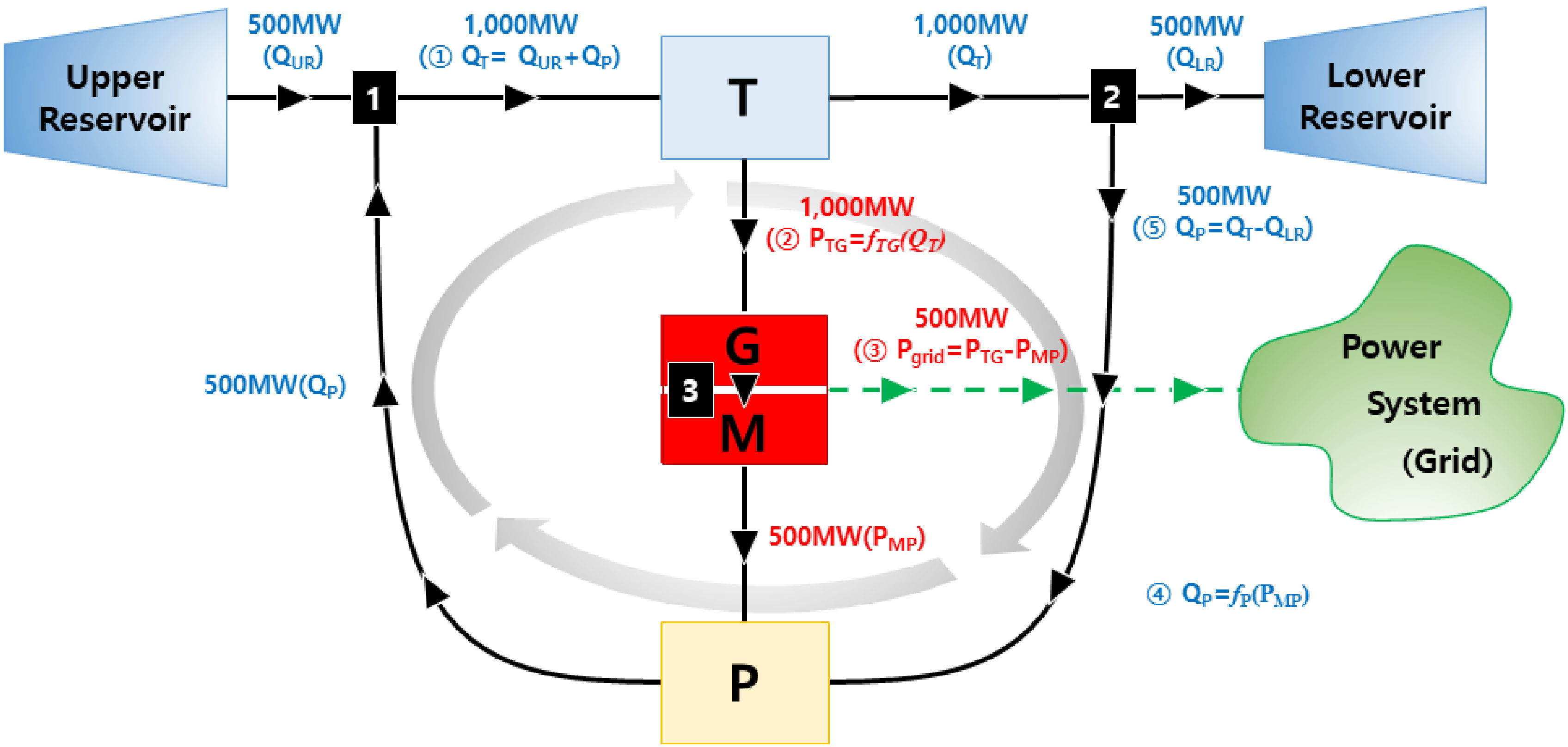


Schematic diagrams and operating ranges of TPSH, AS-PSH and C-PSH: (a) Schematic diagrams; (b) Operating ranges highlighted in blue.



T-PSH coupled with renewables, dynamic transmission control, and flexible AC transmission system devices (Source: NREL)

Generation Mode



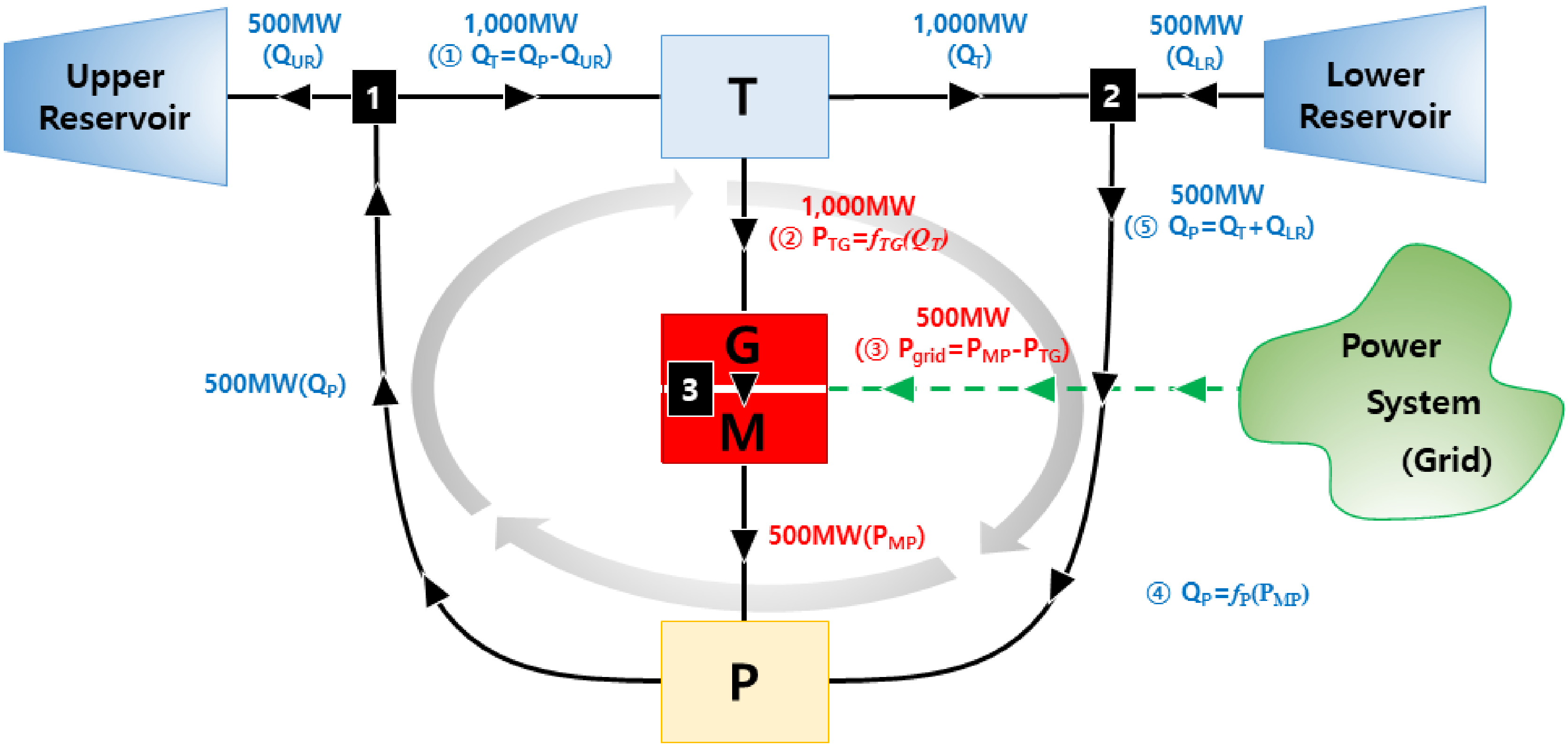
※ Circulation Water

– T= 1,000MW (Q)

– P= 500MW (Q)

∴ Circulation Water가 T>P 일때, Generation Mode가 된다.

Pumping Mode



※ Circulation Water

- T= 500MW (Q)
- P= 1,000MW (Q)

∴ Circulation Water가 T<P 일때, Pumping Mode가 된다.

Ternary Variable P-G

Generator Mode	Pumping Mode
① $Q_T = Q_{UR} + Q_P$	①′ $Q_T = Q_P - Q_{UR}$
② $P_{TG} = f_{TG}(Q_T)$	②′ $P_{TG} = f_{TG}(Q_T)$
③ $P_{Grid} = P_{TG} - P_{MP}$ (D)	③′ $P_{MP} = P_{TG} + P_{Grid}$ $P_{Grid} = P_{MP} - P_{TG}$ (C)
④ $Q_P = f_{MP}(P_{MP})$	④′ $Q_P = f_{MP}(P_{MP})$
⑤ $Q_P = Q_T - Q_{LR}$ $Q_{LR} = Q_T - Q_P$	⑤′ $Q_P = Q_T + Q_{LR}$ $Q_{LR} = Q_P - Q_T$

① $Q_T + Q_{UR} + Q_P = 0$

단, $Q_{UR} \begin{cases} +\text{: 발전(방전)} \\ -\text{: 양수(충전)} \end{cases}$

② $P_{TG} = f_{TG}(Q_T)$

③ $P_{TG} - P_{MP} + P_{Grid} = 0$

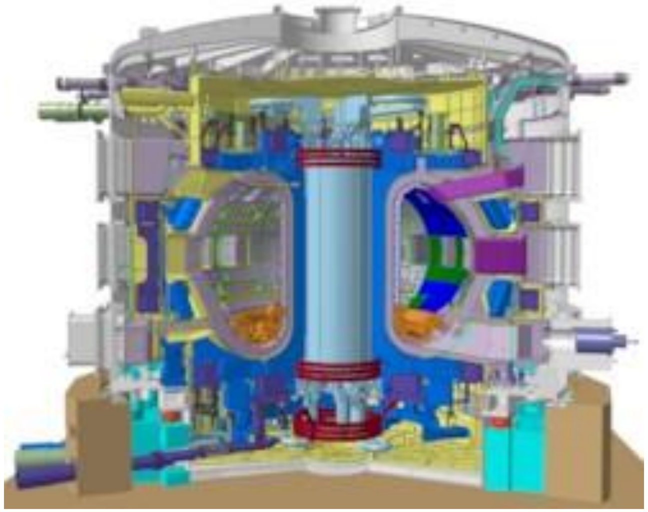
단, $P_{Grid} \begin{cases} +\text{: 양수(충전)} \\ -\text{: 발전(방전)} \end{cases}$

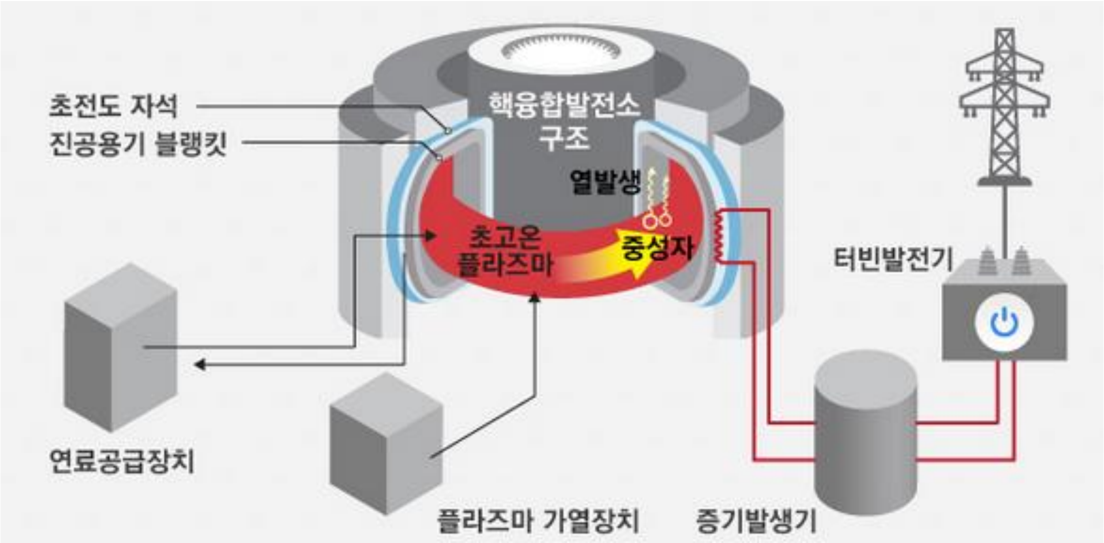
④ $Q_P = f_{MP}(P_{MP})$

⑤ $Q_T + Q_{LR} + Q_P = 0$

단, $Q_{LR} \begin{cases} +\text{: 양수(충전)} \\ -\text{: 발전(방전)} \end{cases}$

VI. Final Energy DNA?
Nuclear Fusion (Artificial Sun)





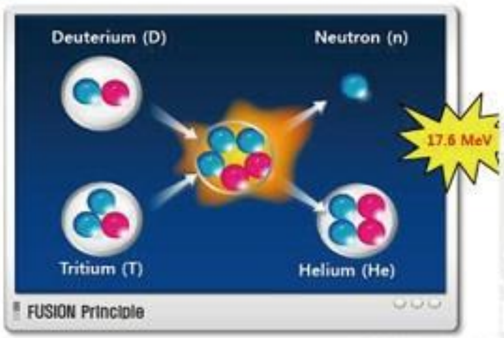
"인류가 1,000년 이후에도 지구에 생존할 수 있을지 여부는 에너지 문제에 달렸다고 해도 과언이 아니다"

	국제핵융합실험로(ITER)	핵융합실증로(DEMO)
건설	2007~2035년	2030~2050년경(예정)
규모	지름 28m, 높이 24m	ITER의 1.1~2배
목적	핵융합에너지 기반 기술 개발, 핵융합 발전 가능성 검증	핵융합 반응부터 전력 생산, 운영까지 상용 수준 핵융합발전소 실증
연료	중수소(D), 삼중수소(T)	중수소(D), 삼중수소(T)
플라즈마 운전 시간	2025년 첫 플라즈마 발생, 최대 1000초 연속운전 달성 목표	24시간 연속운전 목표
에너지증폭률 (Q)	소비전력 대비 10배 전력에 상응하는 열출력(500MWt) 검증	소비전력 대비 40~50배 전력 생산(열출력 기준 2000MWt)
추진 방식	유럽연합(EU), 한국, 중국, 미국, 일본, 러시아, 인도 등 7개국 공동	각 ITER 회원국 개별 추진

자료: ITER 국제기구·한국사업단

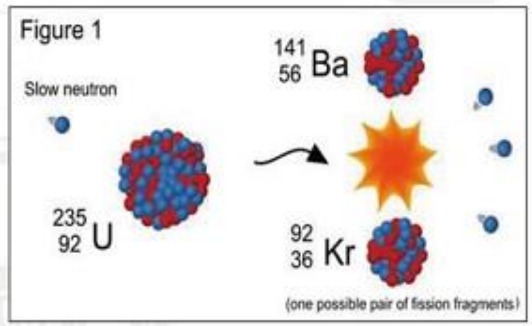
핵융합과 핵분열 반응의 차이점

핵융합 반응

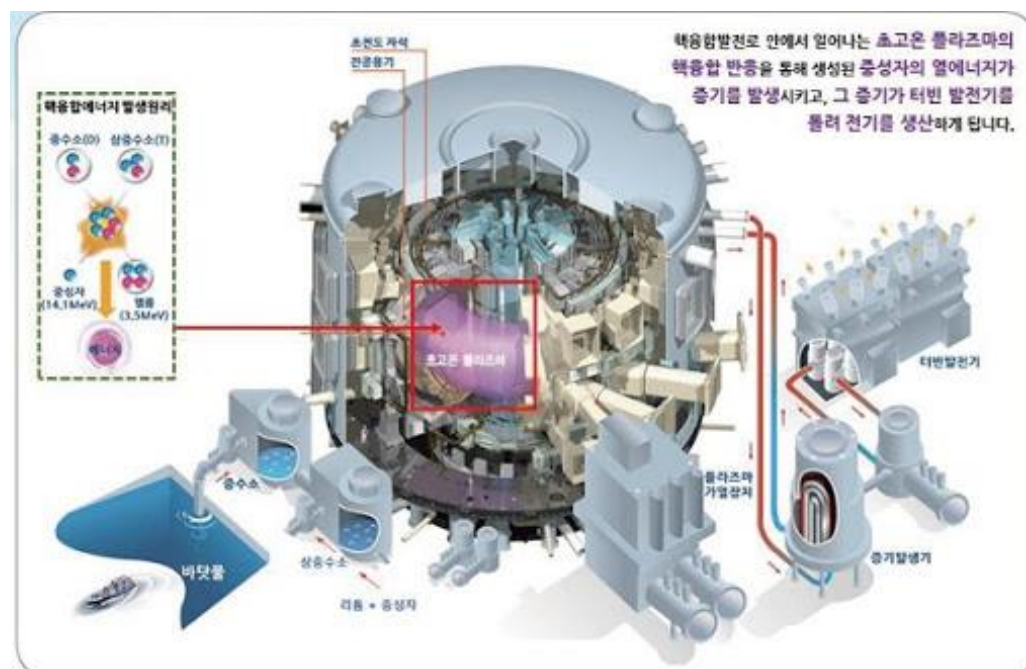


- 질량 (D+T) ~ 5 amu
- 발생 에너지 ~ 17.6 MeV
- 단위질량 당 에너지 ~ 3.5 MeV/amu

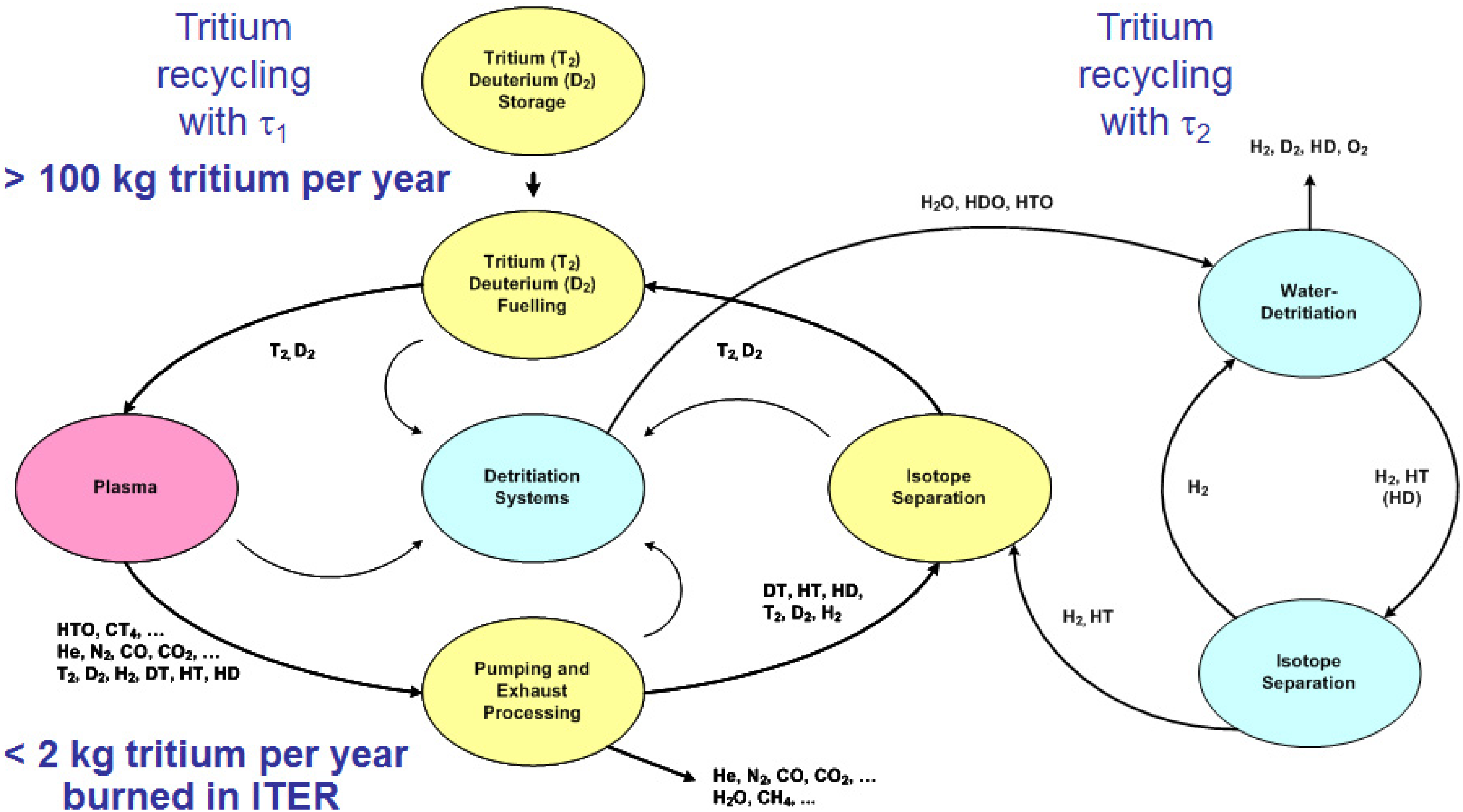
핵분열 반응



- 질량 (U235) ~ 235 amu
- 발생 에너지 ~ 200 MeV
- 단위질량 당 에너지 ~ 0.85 MeV/amu



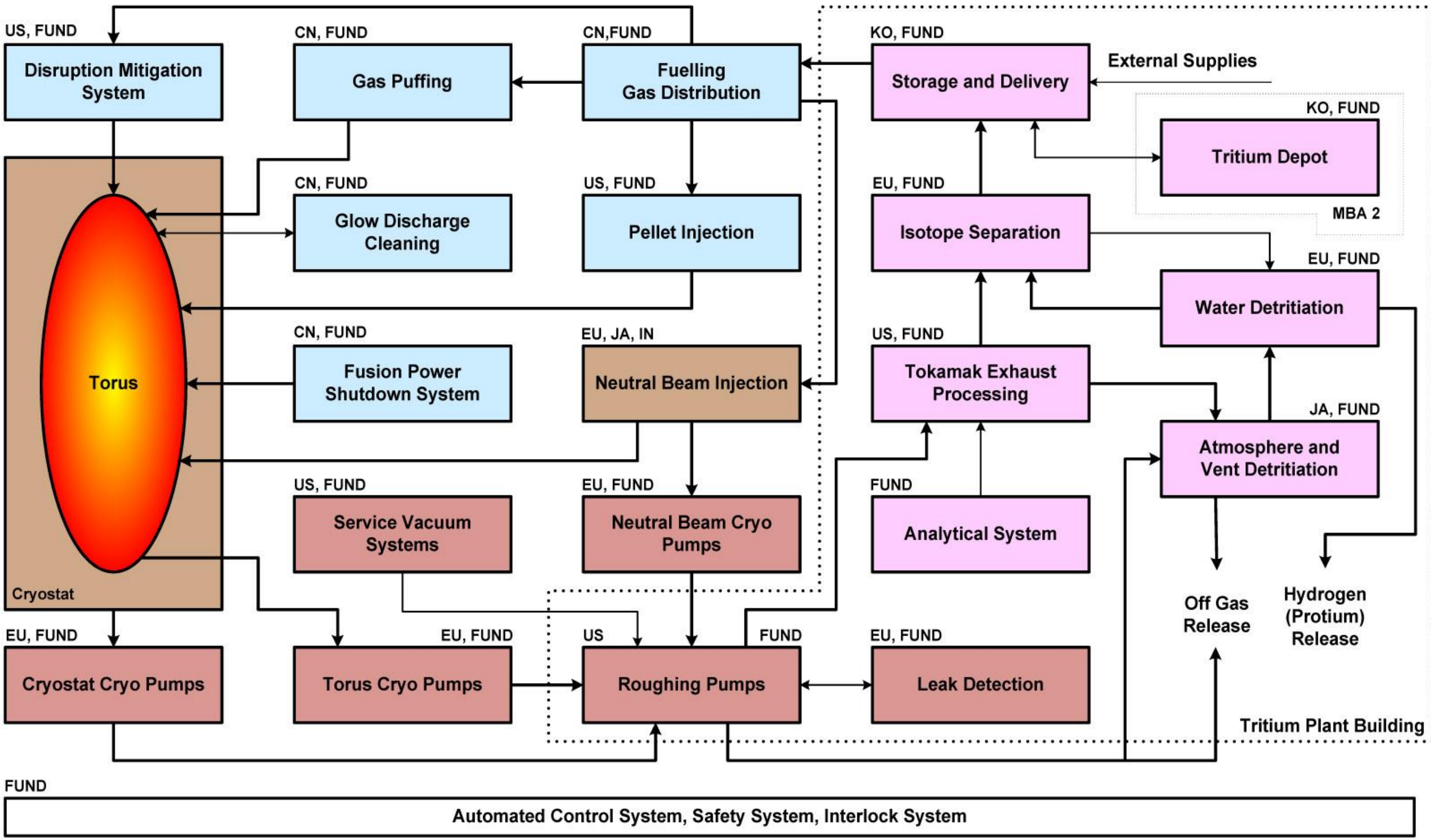
- $D + T \rightarrow 4He(3.5MeV) + n(14.1MeV) + Energy$ (1)
- $n + {}^{6}Li \rightarrow T + {}^{4}He$ (2)



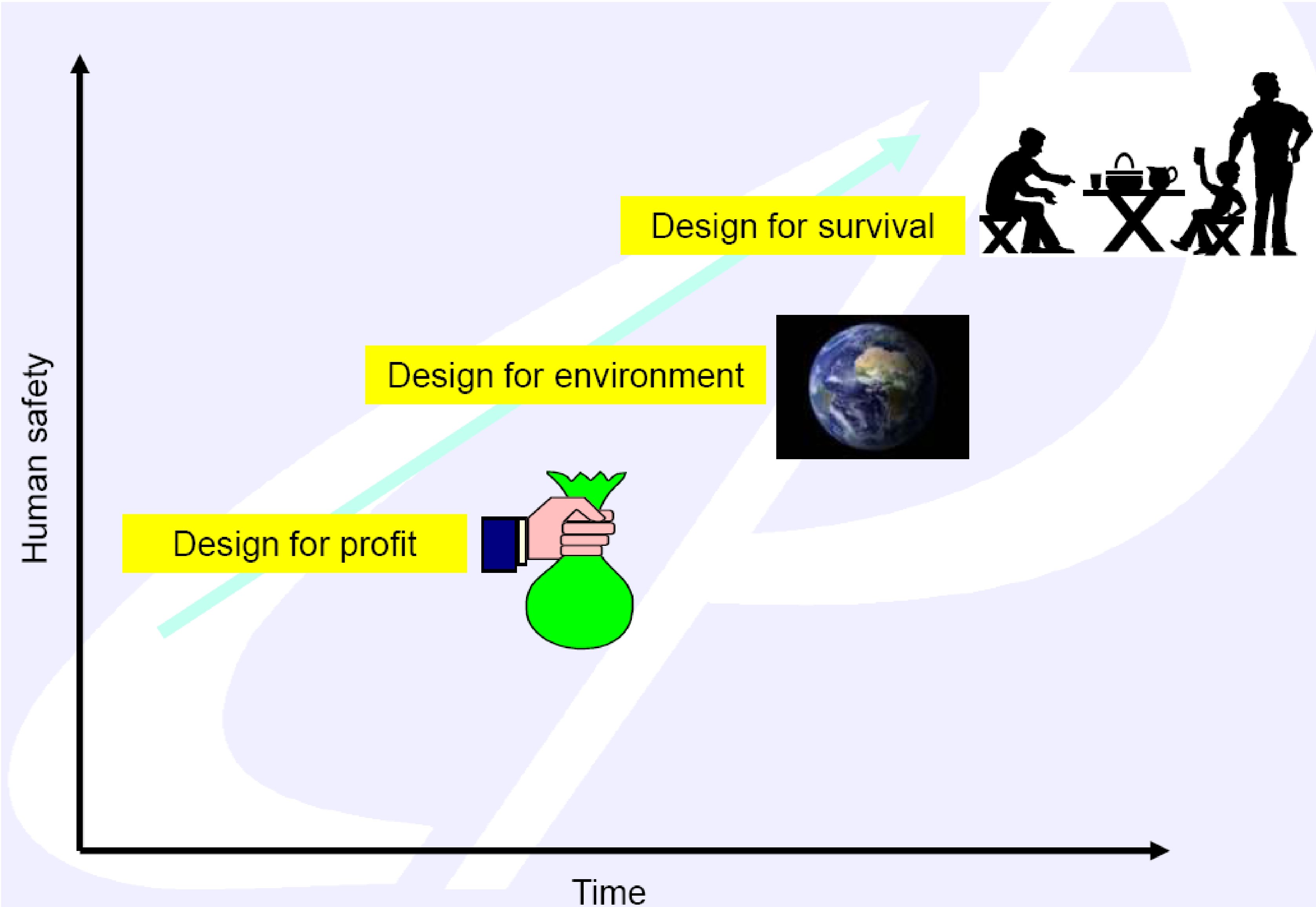
핵융합 반응의 원리와 장점

- 핵융합 연료: 중수소 삼중수소 .
- 바닷물 1리터에는 0.03그램의 중수소가 들어있으며 삼중수소도 리튬에서 쉽게 얻을 수 있다. (리튬매장:지각600년, 바다 1500만 년)
- “핵융합연료 1g= 석유 8톤” (100kw발전기 2대를 하루동안)
- CO2 배출량 없음.
- 방사능량도 원자력의 0.04%. (10~100년이면 재활용이 가능할 정도의 소량의 중저준위 폐기물만 발생.)
- 핵융합로의 온도가 높아질 가능성이 없고, 온도가 떨어지면 핵융합은 자동으로 중단. ->원자력 발전처럼 폭발이나 방사능 누출의 위험이 없음.

Funding for ITER



多樣性과 柔軟性이 이긴다? Why?
융복합이 우성DNA? Why?


Design for survival
Design for environment
Design for profit
Human safety
Time

Energy Evolution

Energy Survival DNA

resistance, absorption, and restoration

Robustness

Diversity

Resiliency

RELIABILITY

Rapidity

Sensitivity

Risk

Adaptability

Toughness

VULNERABILITY

Severity

SECURITY

VI. Summary and Discussion

- **Energy Evolution : Winner DNA!**
- **Conditions for Winner DNA?**
- **DNA of Survival Energy: if yes, What?**
  - **- What is Clean & Sustainable Energy DNA?**
  - **- Human (Citizen) Survival?**
  - **- Near Future: Renewable Generation System?**
  - **- Far Future: Nuclear Fusion Generation System?**
- **For Pulling up Flexibility?**
- **Resilience of Power System?**
- **Human Survival without Electrical Energy?**
- **Elements for Resilient Power System?**
- **What is Making Money(Business Model) in future?**

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Thank for Listening !

Everybody Loves
Energy Survival DNA!

ORCID ID : 0000-0003-0867-6251

Biography

Jaeseok Choi(S'88, M'91, SM'05) was born in Kyeongju, Korea in 1958. He obtained B.Sc., M.Sc. and Ph.D. degrees from Korea University in 1981, 1984 and 1990 respectively. His research interests include Fuzzy Applications, Probabilistic Production Cost Simulation, Reliability Evaluation and Outage Cost Assessment of Power Systems. He was a Post-Doctor at University of Saskatchewan in Canada on 1996. He was also a visiting professor at Cornell University, NY, USA in 2004 to 2007. He is an adjunct professor of Illinois Institute of Technology, IL, USA since 2008. Since 1991, he has been on the faculty of Gyeongsang National University, Jinju, where he is a professor. He is 2020 president and Fellow of KIEE.