A new IAEA in-house capability for integrated system analysis - FRAMES

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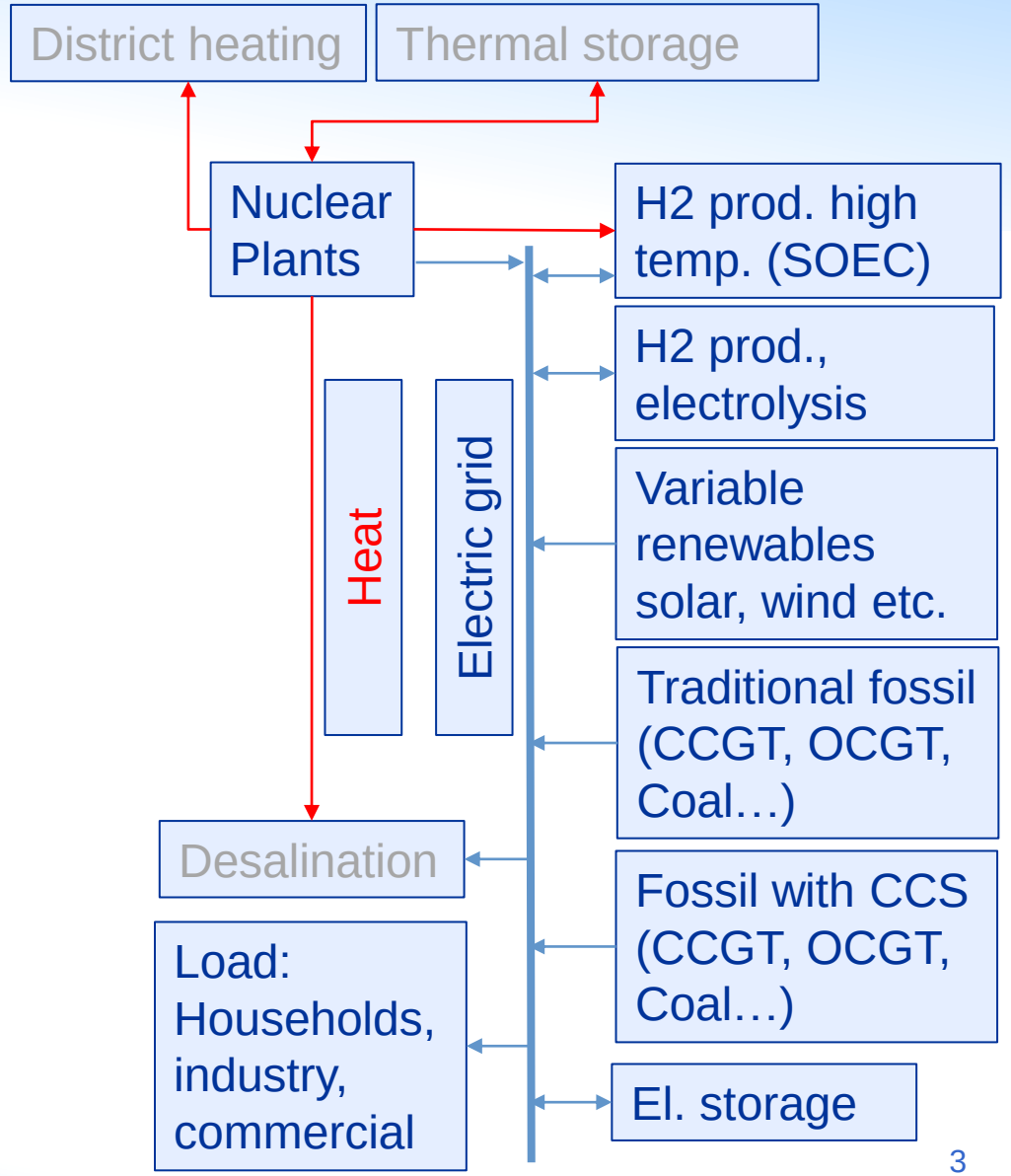
Content of this presentation

- FRAMES overview
- Objectives of FRAMES
- Example model: hydrogen implementation
- Conclusions

Integrated Energy System Analysis: FRAMES

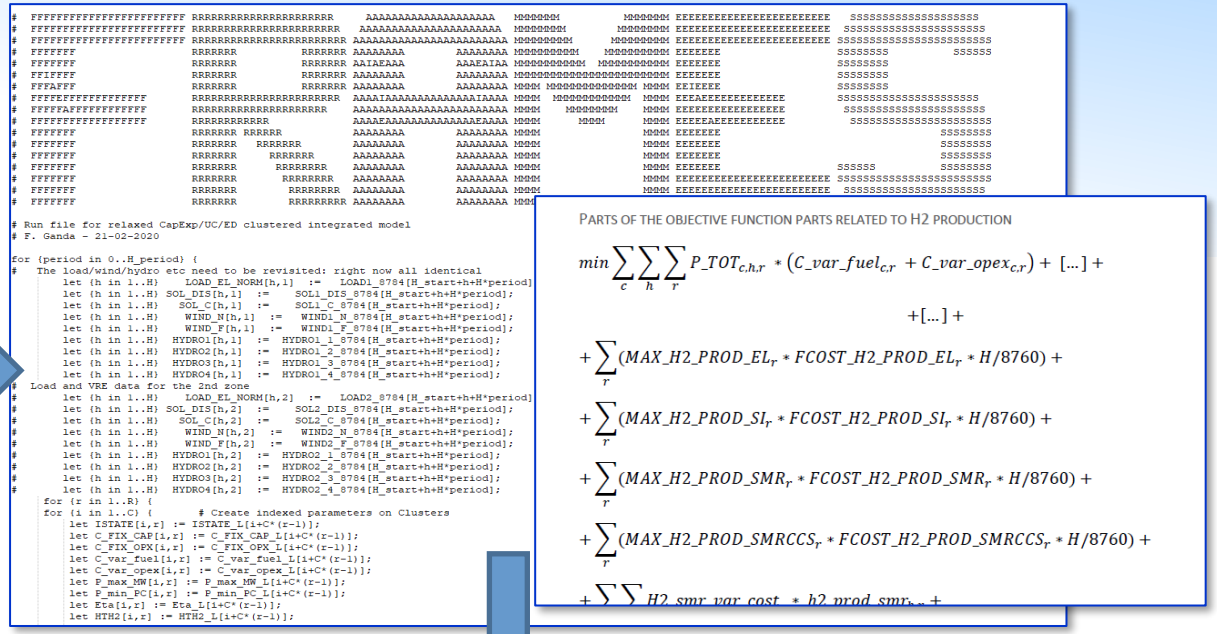
- Growing interest in integrated energy systems (Member States and IAEA), in particular with nuclear and renewables
- IAEA is developing an in-house capability (FRAMES)
- Can quantify the value that nuclear brings to low-carbon systems, and inform policy
- FRAMES can highlight the value of Gen IV NES (high temperature heat for non-el. applications, load following etc.), for example.



IAEA-FRAMES in a nut-shell

INPUT (Most important parameters)

- Demand profile (hourly for 1 y)
- VRE load factors (hourly for 1 y)
- CAPEX, OPEX & other costs of each technology
- Operational constraints (ramp rates, min up/down time etc.)
- CO_2 intensity of each technology
- Deployment limits of each technology
- CO_2 emissions of the entire system



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# Run file for relaxed CapExp/UC/ED clustered integrated model
# F. Ganda - 21-02-2020

for {period in 0..H_period} {
#   The load/wind/hydro etc need to be revisited: right now all identical
      let {h in 1..H}     LOAD_EL_NORM[h,1]  :=   LOAD1_8784[H_start+h+H*period];
      let {h in 1..H} SOL_DIS[h,1]  :=    SOL1_DIS_8784[H_start+h+H*period];
      let {h in 1..H}   SOL_C[h,1]  :=    SOL1_C_8784[H_start+h+H*period];
      let {h in 1..H}    WIND_N[h,1]  :=   WIND1_N_8784[H_start+h+H*period];
      let {h in 1..H}    WIND_F[h,1]  :=   WIND1_F_8784[H_start+h+H*period];
      let {h in 1..H}  HYDRO1[h,1]  :=  HYDRO1_1_8784[H_start+h+H*period];
      let {h in 1..H}  HYDRO2[h,1]  :=  HYDRO1_2_8784[H_start+h+H*period];
      let {h in 1..H}  HYDRO3[h,1]  :=  HYDRO1_3_8784[H_start+h+H*period];
      let {h in 1..H}  HYDRO4[h,1]  :=  HYDRO1_4_8784[H_start+h+H*period];
#  Load and VRE data for the 2nd zone
#     let {h in 1..H}     LOAD_EL_NORM[h,2]  :=   LOAD2_8784[H_start+h+H*period];
#     let {h in 1..H} SOL_DIS[h,2]  :=    SOL2_DIS_8784[H_start+h+H*period];
#     let {h in 1..H}   SOL_C[h,2]  :=    SOL2_C_8784[H_start+h+H*period];
#     let {h in 1..H}    WIND_N[h,2]  :=   WIND2_N_8784[H_start+h+H*period];
#     let {h in 1..H}    WIND_F[h,2]  :=   WIND2_F_8784[H_start+h+H*period];
#     let {h in 1..H}  HYDRO1[h,2]  :=  HYDRO2_1_8784[H_start+h+H*period];
#     let {h in 1..H}  HYDRO2[h,2]  :=  HYDRO2_2_8784[H_start+h+H*period];
#     let {h in 1..H}  HYDRO3[h,2]  :=  HYDRO2_3_8784[H_start+h+H*period];
#     let {h in 1..H}  HYDRO4[h,2]  :=  HYDRO2_4_8784[H_start+h+H*period];
    for {r in 1..R} {
    for {i in 1..C} {       # Create indexed parameters on Clusters
        let ISTATE[i,r] := ISTATE_L[i+C*(r-1)];
        let C_FIX_CAP[i,r] := C_FIX_CAP_L[i+C*(r-1)];
        let C_FIX_OPX[i,r] := C_FIX_OPX_L[i+C*(r-1)];
        let C_var_fuel[i,r] := C_var_fuel_L[i+C*(r-1)];
        let C_var_opex[i,r] := C_var_opex_L[i+C*(r-1)];
        let P_max_MW[i,r] := P_max_MW_L[i+C*(r-1)];
        let P_min_PC[i,r] := P_min_PC_L[i+C*(r-1)];
        let Eta[i,r] := Eta_L[i+C*(r-1)];
        let HTH2[i,r] := HTH2_L[i+C*(r-1)];
```

PARTS OF THE OBJECTIVE FUNCTION PARTS RELATED TO H2 PRODUCTION

$$min \sum_c \sum_h \sum_r P\_TOT_{c,h,r} * (C\_var\_fuel_{c,r} + C\_var\_opex_{c,r}) + [\ldots] +$$

$$+[\ldots] +$$

$$+ \sum_r (MAX\_H2\_PROD\_EL_r * FCOST\_H2\_PROD\_EL_r * H/8760) +$$

$$+ \sum_r (MAX\_H2\_PROD\_SI_r * FCOST\_H2\_PROD\_SI_r * H/8760) +$$

$$+ \sum_r (MAX\_H2\_PROD\_SMR_r * FCOST\_H2\_PROD\_SMR_r * H/8760) +$$

$$+ \sum_r (MAX\_H2\_PROD\_SMRCCS_r * FCOST\_H2\_PROD\_SMRCCS_r * H/8760) +$$

$$+ \sum \sum H2\_smr\_var\_cost * h2\_prod\_smr_{r,\ldots} +$$

OUTPUT (Most important)

- Optimal capacity of each technology (with respect to cost) (Nuclear, coal, gas, VRE, batteries etc.)
- Optimal power level of each technology (hourly)
- Total system costs
- Total curtailment of renewables
- Transmission power flow if multi-zone model
- Hydrogen production if included

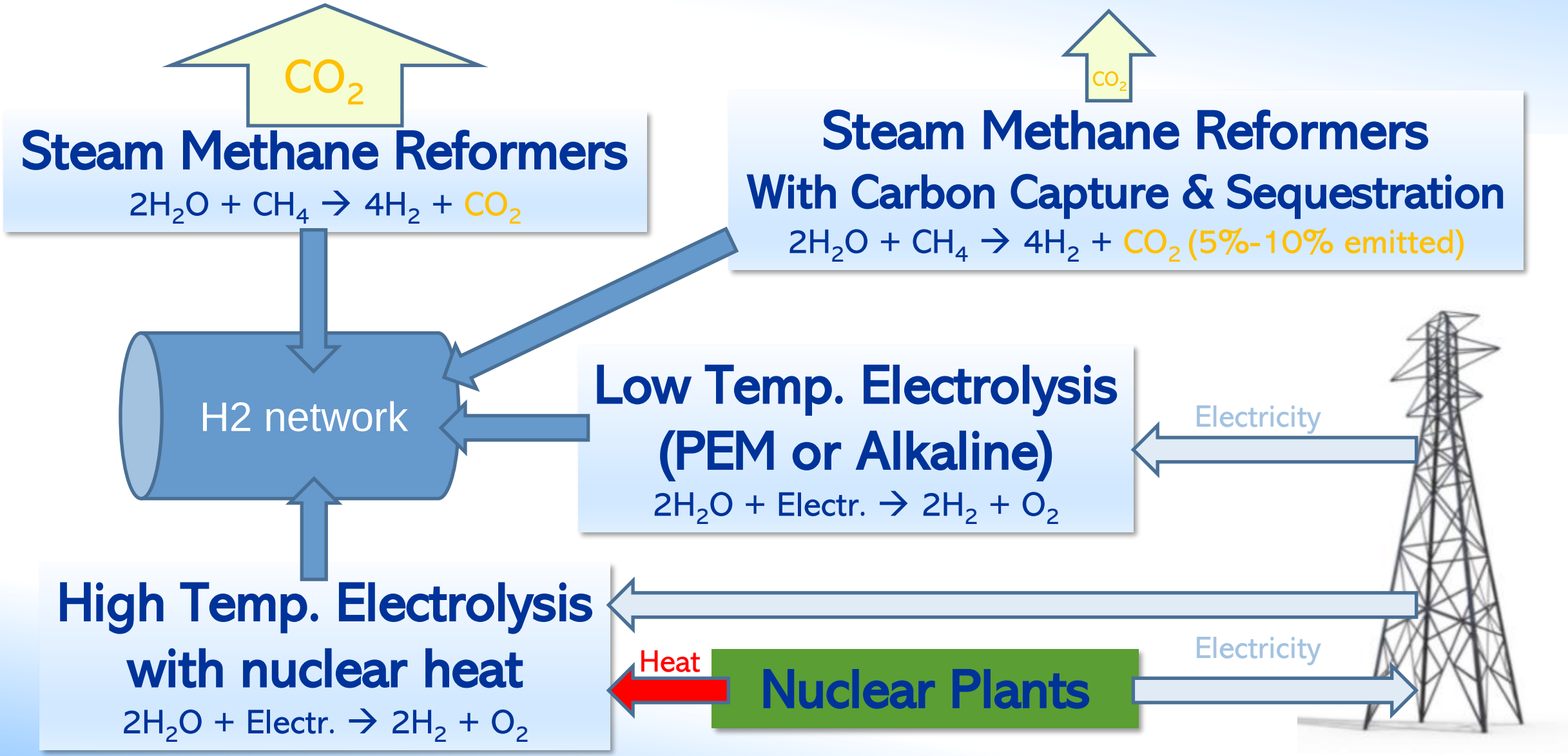
- **FRAMES finds the *optimum*, i.e. the "*best that can be done*" with a given system in terms of electricity, H_2 and heat production.**
- ***This provides a quantitative and defensible basis for informing policy making*, as well as to support a variety of technical analyses (e.g. technical parameters for Gen IV systems).**

Objectives of FRAMES

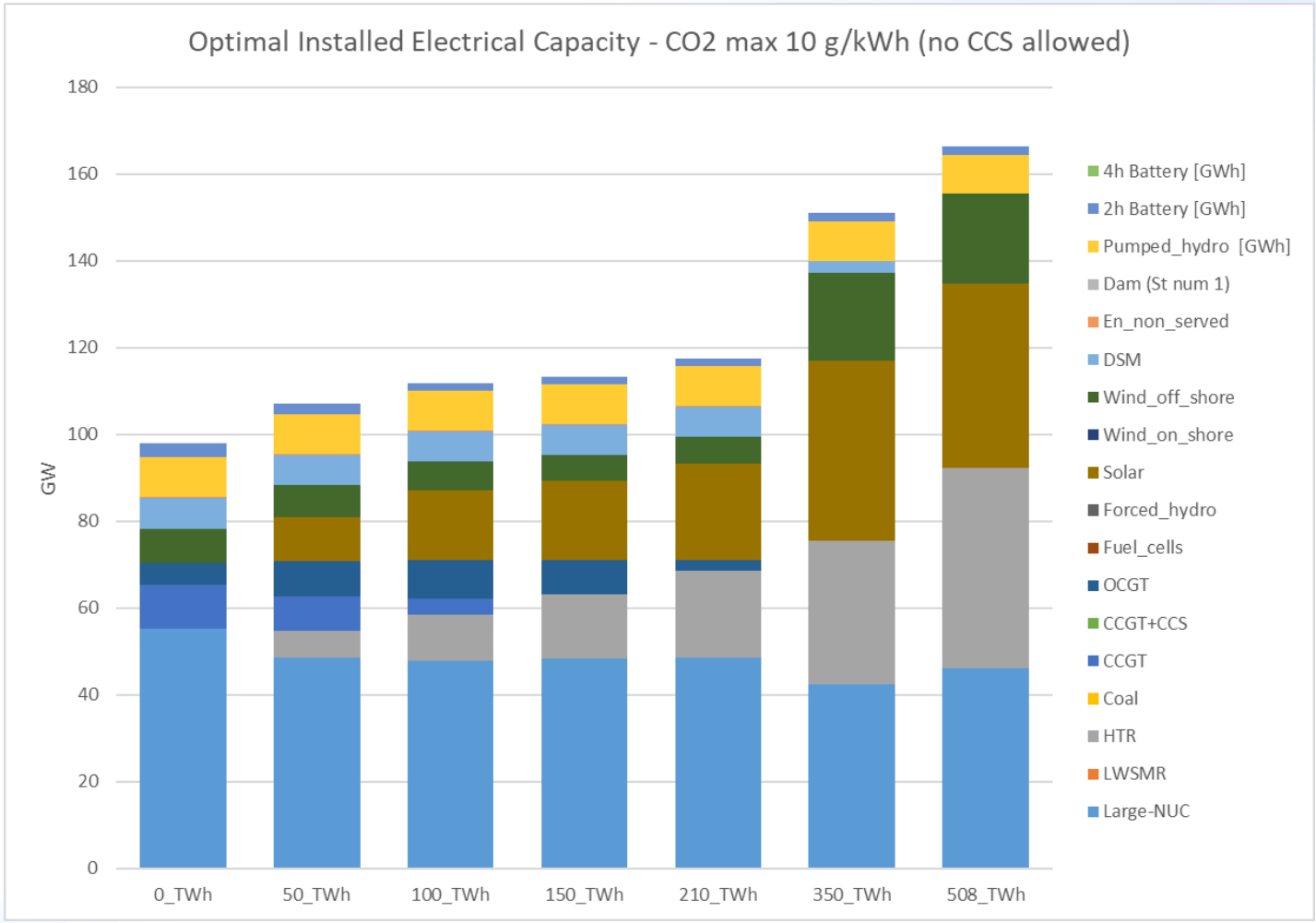
For quantitative and defensible analyses:

- On the role that nuclear energy can play in present and future electricity systems;
- On the optimal grid integration of advanced (e.g. Gen IV) nuclear technologies;
- On the optimal share of nuclear and renewables for each particular grid, demand profile, VRE potential etc.;
- On the optimal policy mechanisms to achieve climate targets;
- On the flexibility requirements for nuclear power plants in future energy systems (useful for technology developers, e.g. of Gen IV systems);
- On non-electric application of nuclear energy (cogeneration, energy storage, multigeneration etc.), e.g. in synergy with advanced nuclear technologies.

Example of model in FRAMES: H_2



Optimal H_2/electricity production strategy for decarbonized system (FRAMES example result)



With increasing H_2 demand, the optimal deployment of Gen IV high temperature reactors for the cogeneration of thermal H_2 and electricity increases.

Conclusions

- The IAEA is developing FRAMES as an in-house modelling capability for integrated systems assessment.
- FRAMES can help quantify the value that nuclear brings to low-carbon systems, especially with nuclear and renewables,
- It can inform policy and other techno-economic evaluations: E.g. features of Gen IV reactors that make them advantageous for the decarbonized systems of the future.
- Currently, FRAMES is used to support IAEA's messages on nuclear energy's role in decarbonization strategies (for example at COP26).
- Collaborations on complex energy system modelling and methodologies with MSs could be considered in the future.

IAEA
International Atomic Energy Agency

Thank you!