IRENA FlexTool

TRAINING FOR MENA

SESSION 4: Modelling flexibility options from supply to demand-side flexibility

Flexibility options according to IRENA

Flexibility needs to be harnessed in all sectors of the energy system

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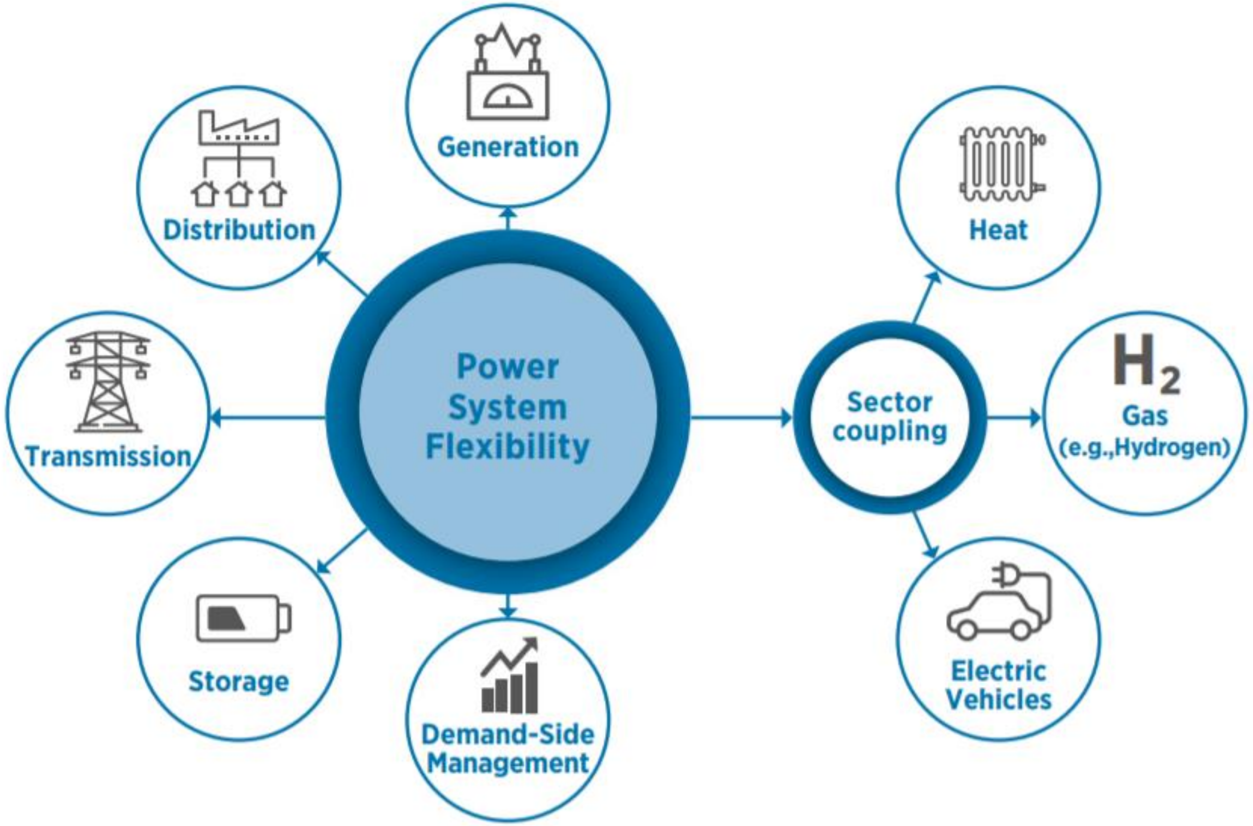
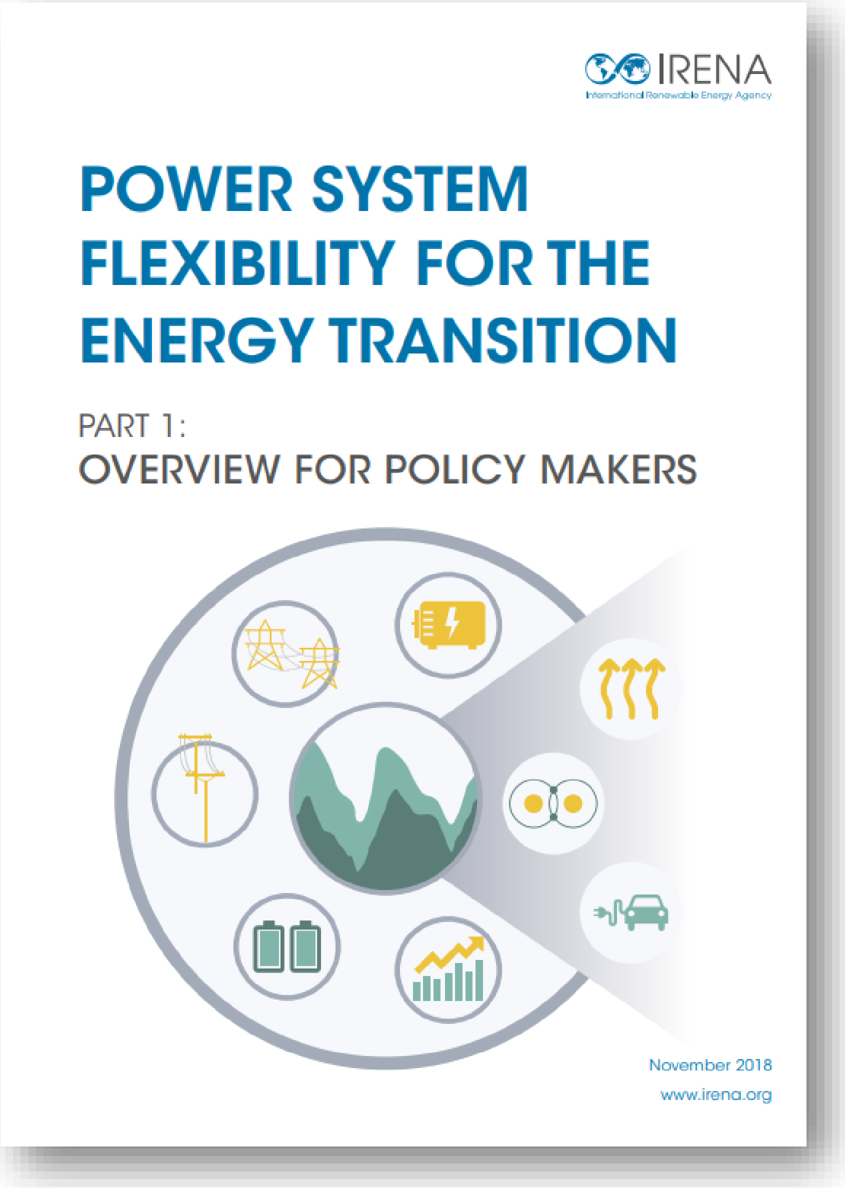
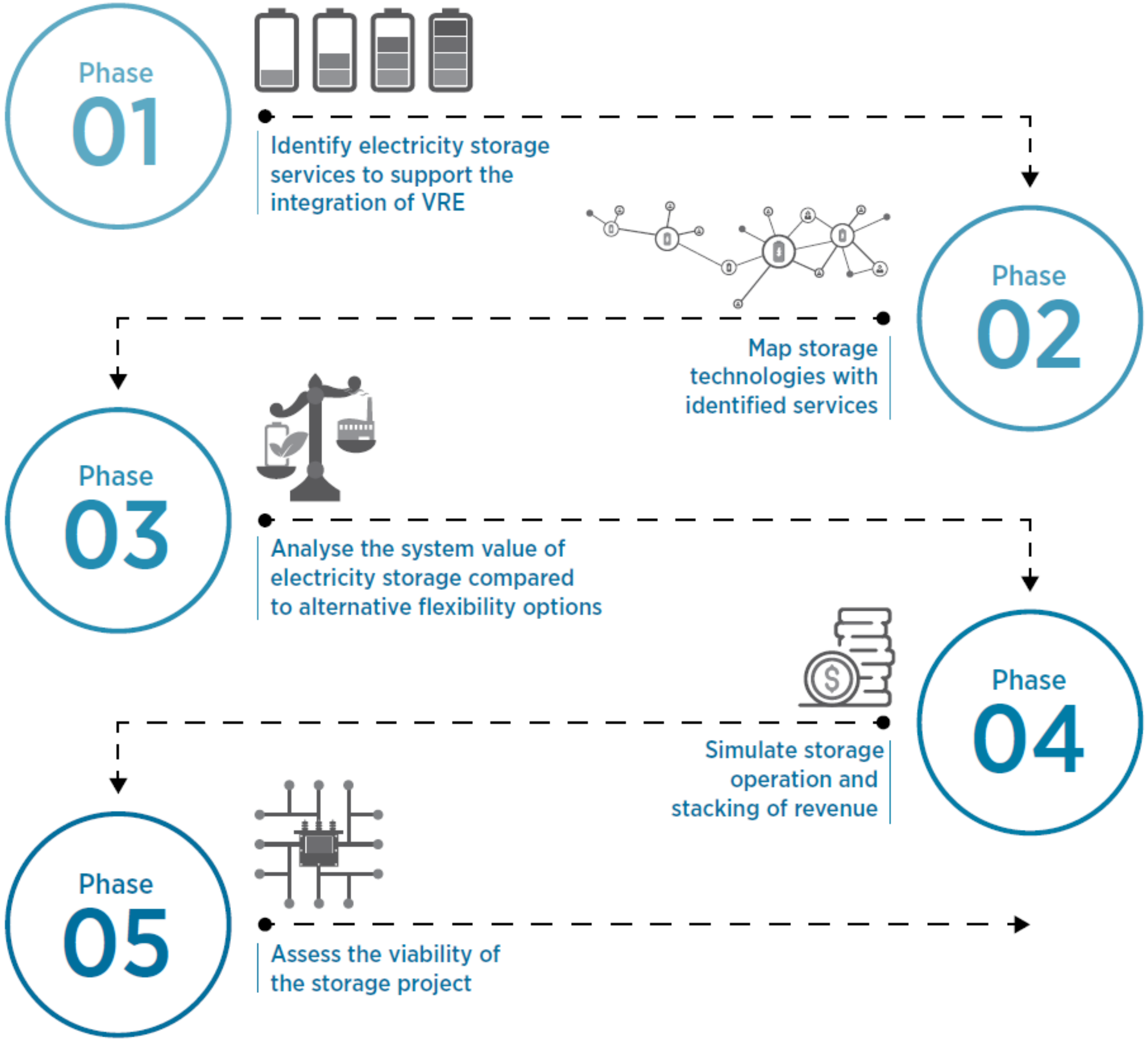
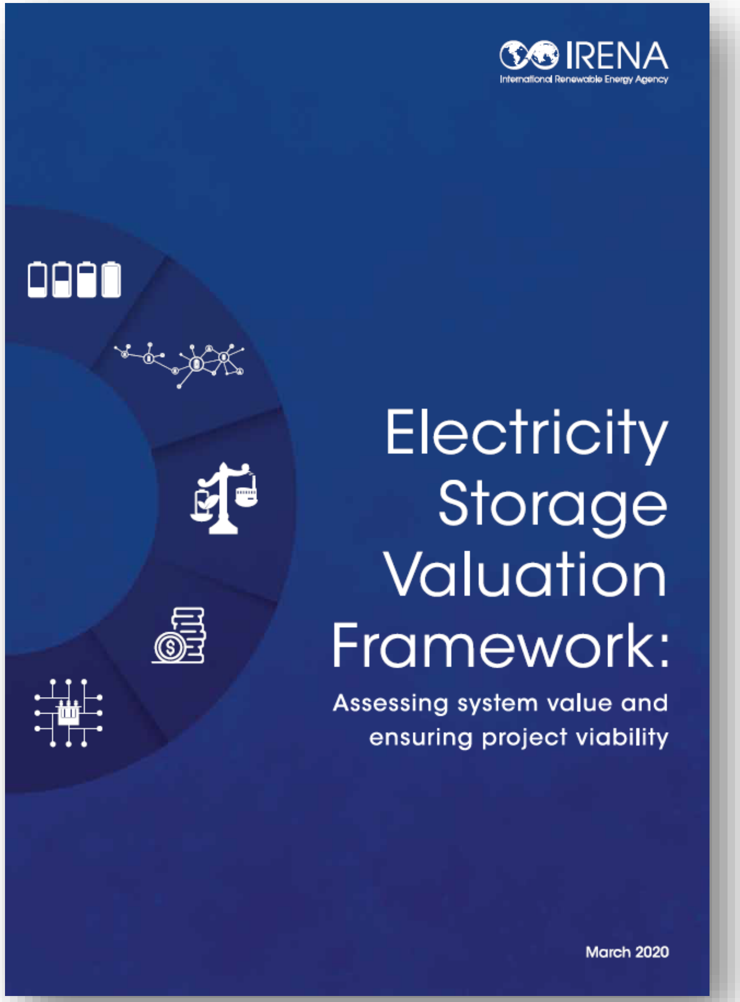




Electricity Storage

Electricity Storage Valuation Framework





Modeling electricity storage in IRENA FlexTool

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- Electricity storage is defined in “**unit_type**” sheet, with few additions compared to other generators:
  - Efficiency (%) – Discharging efficiency
  - Eff.charge (%) – Charging efficiency
  - Self discharge loss (% of content per hour) – if any

- In “**units**” sheet the following is defined:
  - Capacity (MW) – Installed capacity in MW
  - Storage (MWh) – Maximum storage capacity in MWh
  - Storage start/finish – Initial and final state of the storage

- If storage type is pumped hydro storage it is possible that the unit has a natural inflow, which could be defined in “**ts_inflow**” sheet

Investment mode for batteries

Two options: Fixed P/E ratio or free optimisation

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Option 1: Fix power to energy ratio

- Model the batteries with a fixed power to energy ration, this is to say, with a fixed discharge duration (*e.g.,* 2 hours or 4 hours batteries
- **Only investment cost required is the one to invest in energy (battery cells)**
- In this example the model would only consider 1 hour duration batteries in optimisation

unit type	inv.cost/kW	inv.cost/kWh	fixed kW/kWh ratio
battery		80	1.000

Option 2: Free optimisation of power and energy

- It is also possible to optimise separately power and energy
- In this case there is no need to defined a P/E ratio but an investment cost for power (inverter) and energy would be required

unit type	inv.cost/kW	inv.cost/kWh	fixed kW/kWh ratio
battery	20	80	

Electric Vehicles

Smart Charging of Electric Vehicles

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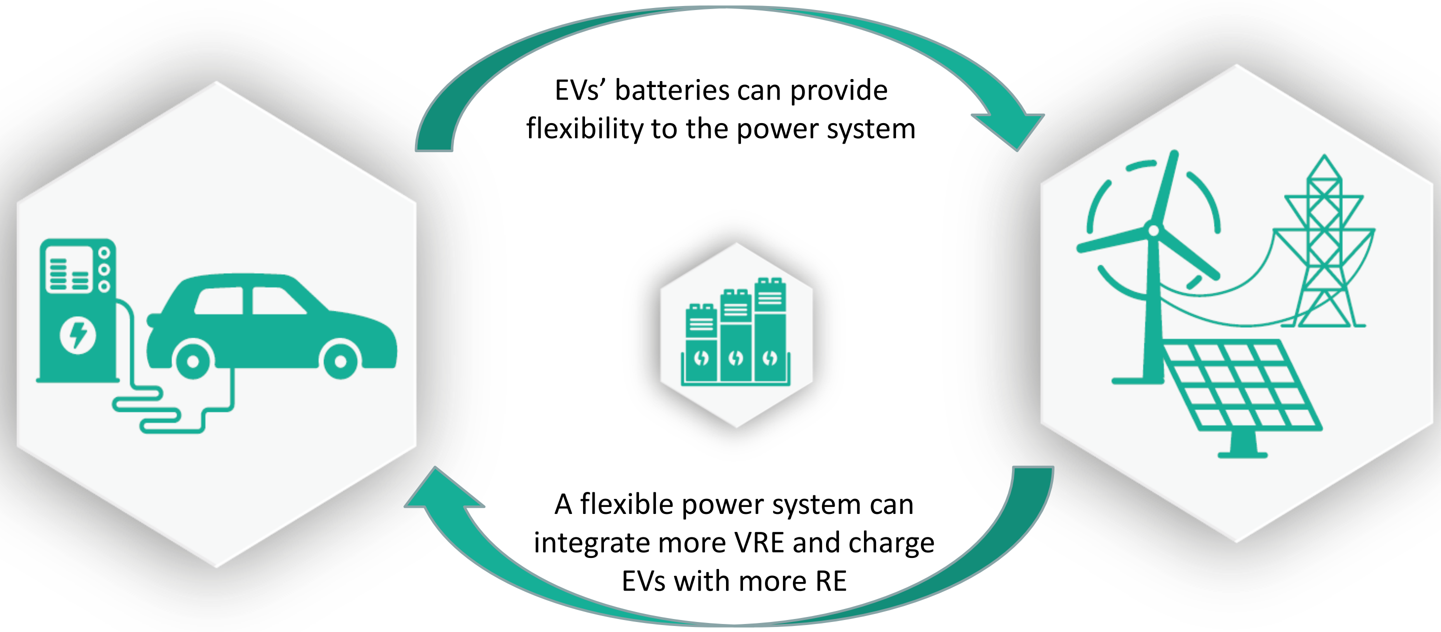
EVs decarbonize the power sector



VRE decarbonize the transport sector

Smart charging is key to take advantage of the synergies between clean transport and low carbon electricity

Fuente: Innovation outlook: Smart charging for electric vehicles, IRENA, 2019

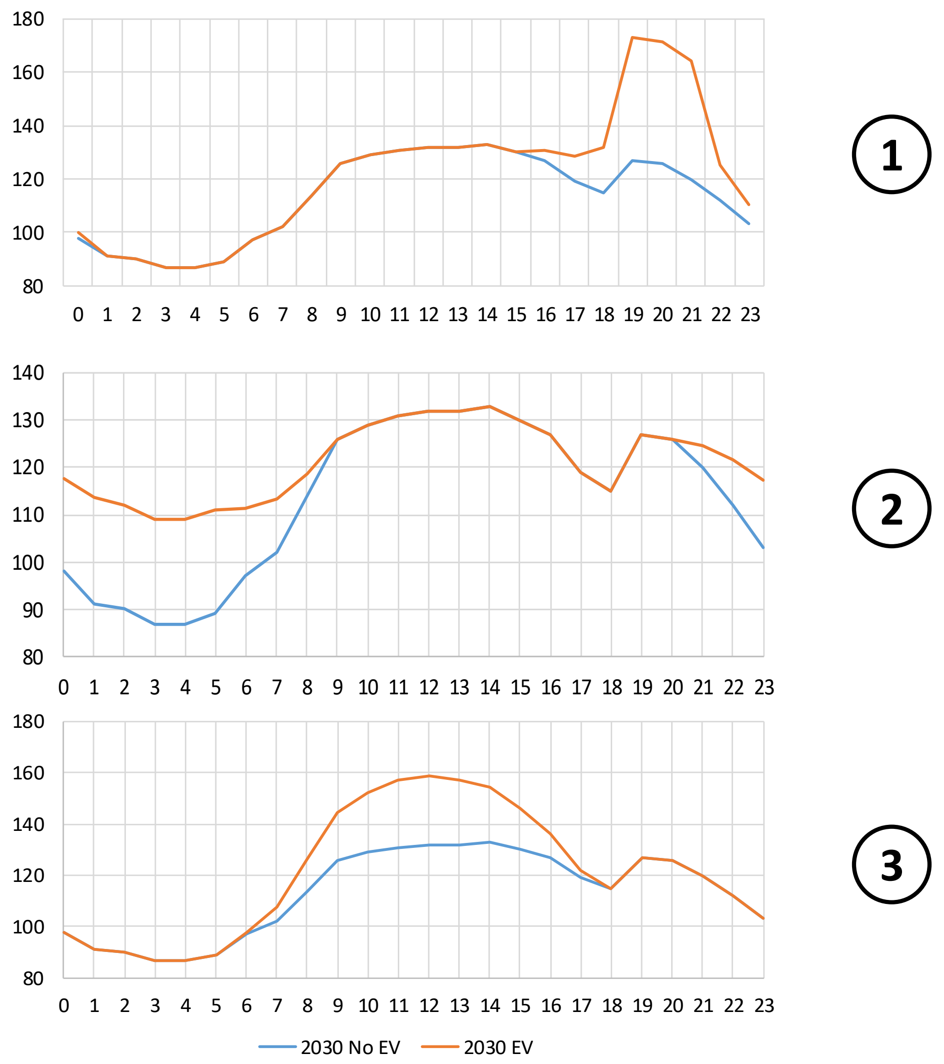
Modelling unidirectional charging of EVs

Pre-calculating demand profiles

- EVs as predefined demand profiles that are added on top of the original demand curve

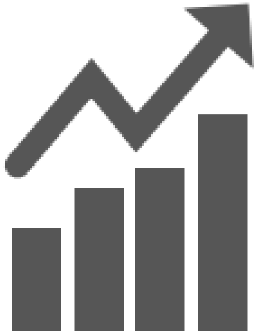
- Three charging scenarios:
  1. Evening uncontrolled charging
     - As soon as EVs arrive home, they charge at maximum power
  2. Night controlled charging
     - Charge is distributed along the night
  3. Day controlled charging
     - Charge coincides with the solar PV profile

- **In FlexTool**: Sum these profiles to the demand curve and add it in "**ts_energy**" sheet



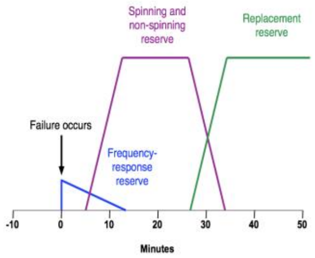
Modelling Vehicle-to-Grid in FlexTool (V2G)

Electromobility Grid



Demand

- Defined demand profile in “ts_energy” sheet
- This demand would represent discharge of battery because of mobility
- We need to estimate this demand



Reserves

- Define reserve profile in “ts_reserve” sheet
- This is used to represent the amount of EVs that are connected to grid in a time period
- Existing software to estimate this

Define a unit that transfers energy from mobility grid to electricity grid and vice versa

$$P_{tot} = \alpha * \sum P_{Chargers}$$

$$E_{tot} = \alpha * \sum E_{battery}$$

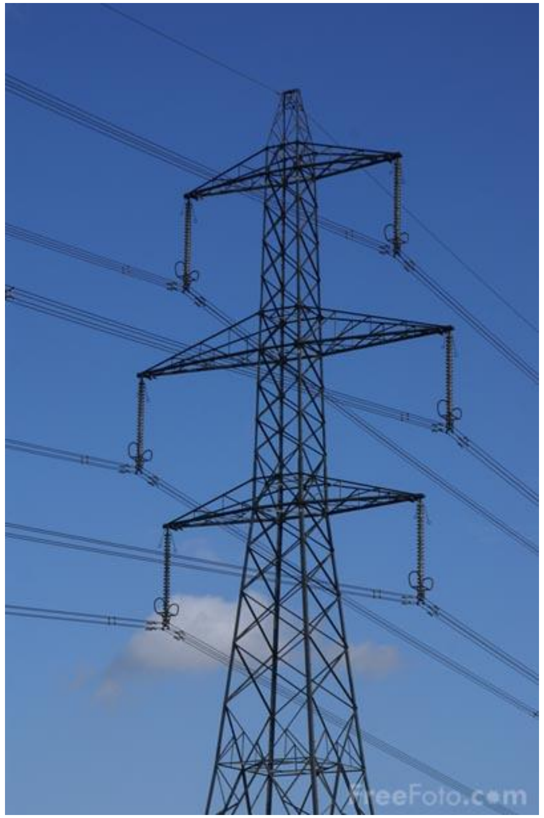
$$\alpha = Simultaneity\ factor$$

Discharge →

← Charge

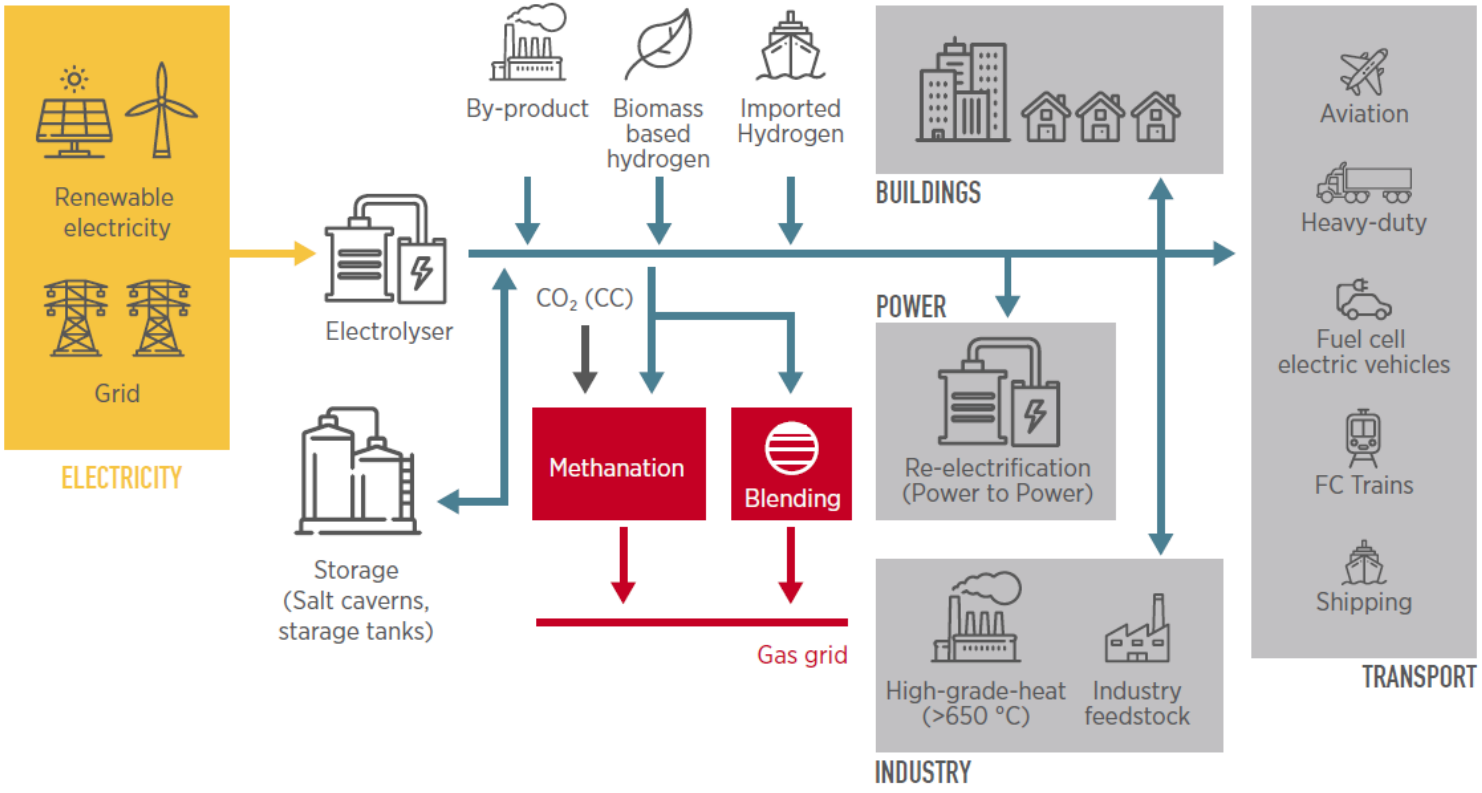
→ Ancillary services →

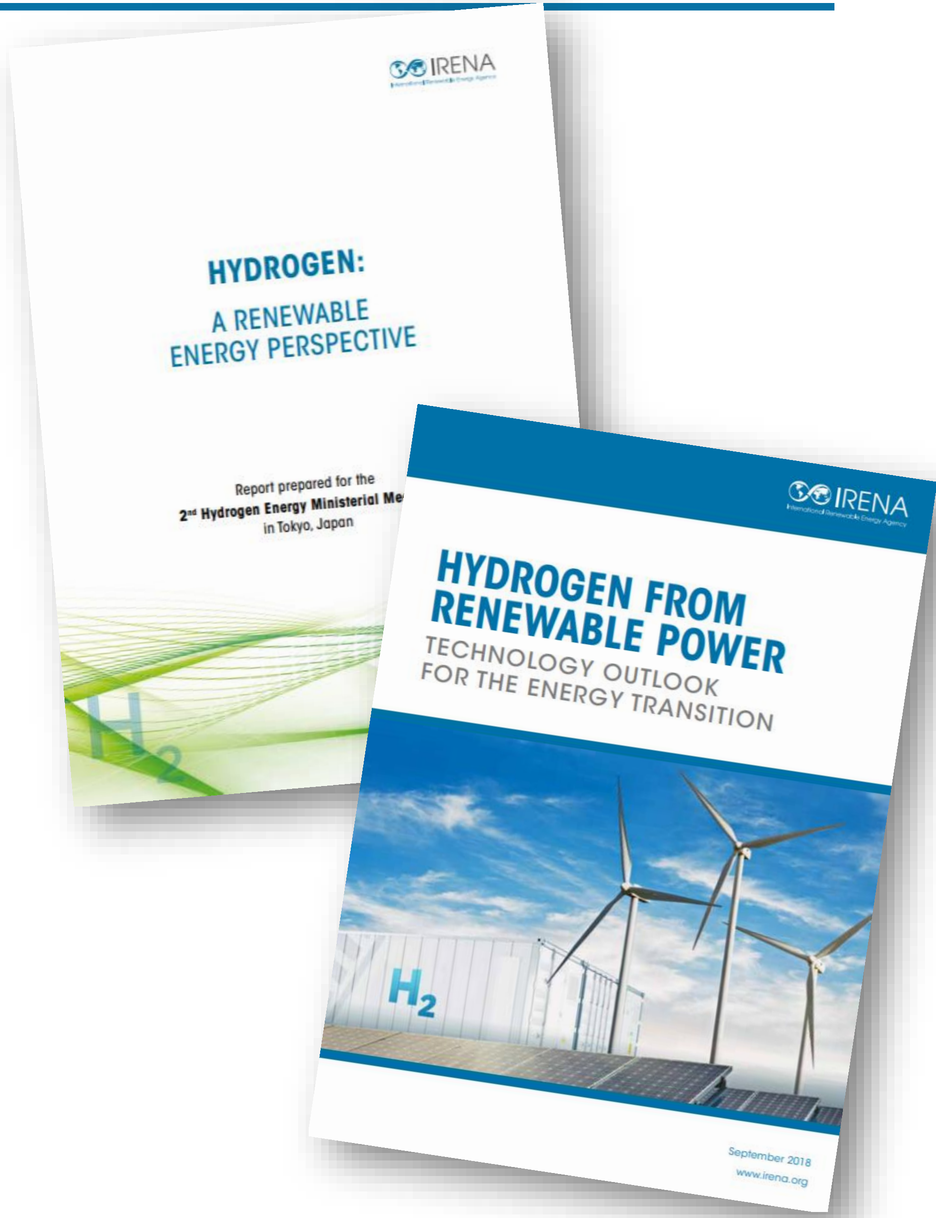
Electricity Grid



Power-to-hydrogen

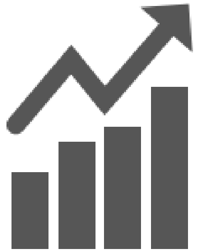
Green hydrogen for the energy transition





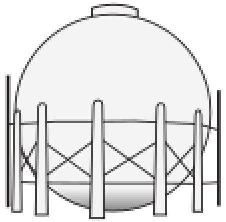
Modelling Power-to-hydrogen in IRENA FlexTool

Hydrogen Grid



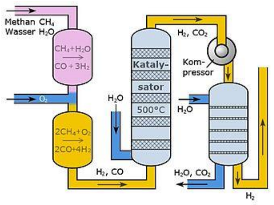
Demand

- Defined demand profile in “ts_energy” sheet
- This demand would represent hydrogen demand in the system



Hydrogen Storage

- Defined exactly the same as electricity storage but in hydrogen grid (see slides on electricity storage)
- In FlexTool a hydrogen network with different nodes could also be modelled



Other production methods

- In hydrogen grid other methods of hydrogen production can also be modelled in a simplified way
- Examples: steam methane reforming (SMR)

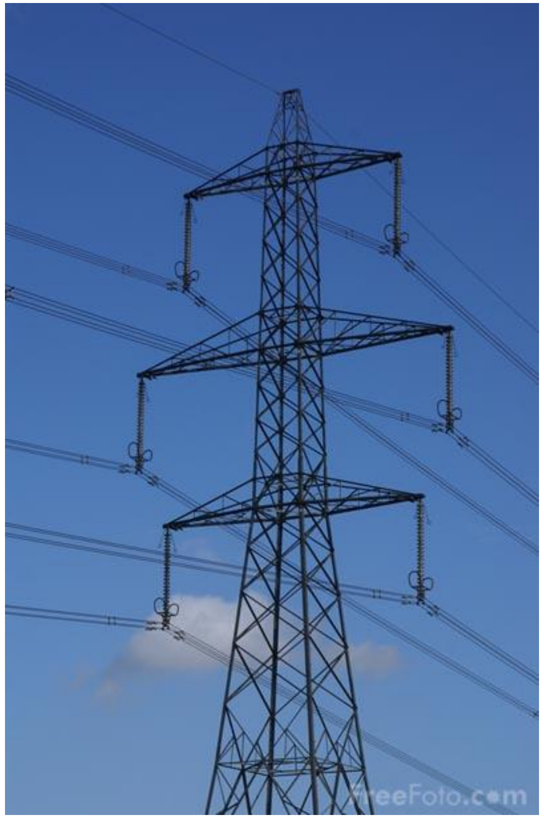
Electrolyser

(NEXT SLIDE)

Fuel Cell

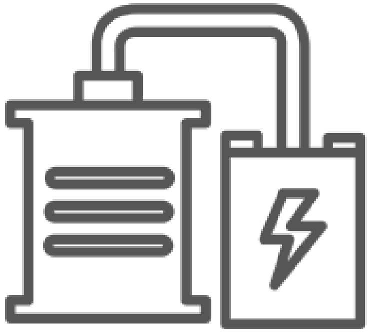
(NEXT SLIDE)

Electricity Grid



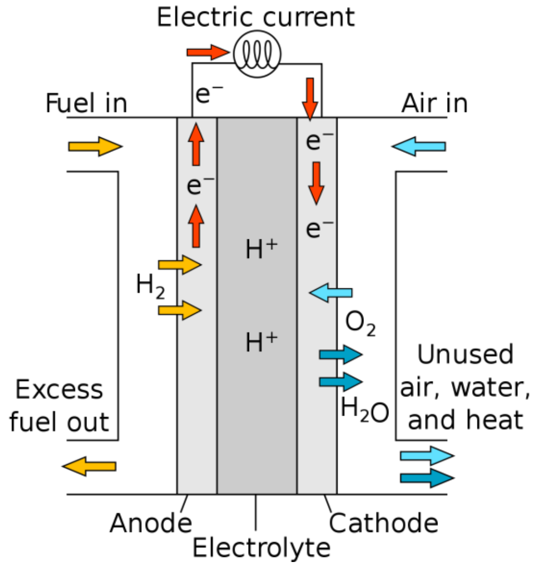
Electrolysers and Fuel Cells

IRENA FlexTool



- Unit that absorbs electricity and converts it to hydrogen to be used in that grid
- In "**unit_type**" define the main characteristics of the electrolyser depending on its chemistry
  - For example: efficiency ("**conversion eff.**"), ramping capabilities, lifetime, etc.
- In "**units**" define installed capacity per node as with generators
- Main issue with electrolysers today is lack of real data about their characteristics

- Unit that absorbs hydrogen and converts it back to electricity
- In "**unit_type**" define main characteristics of the fuel cell. Note that efficiency is also "**conversion eff.**"
- In "**units**" define installed capacity per node as with generators
- Likewise we can model a gas turbine or any other generator that uses hydrogen as an input



Transmission

Transfers, 1/2

IRENA FlexTool

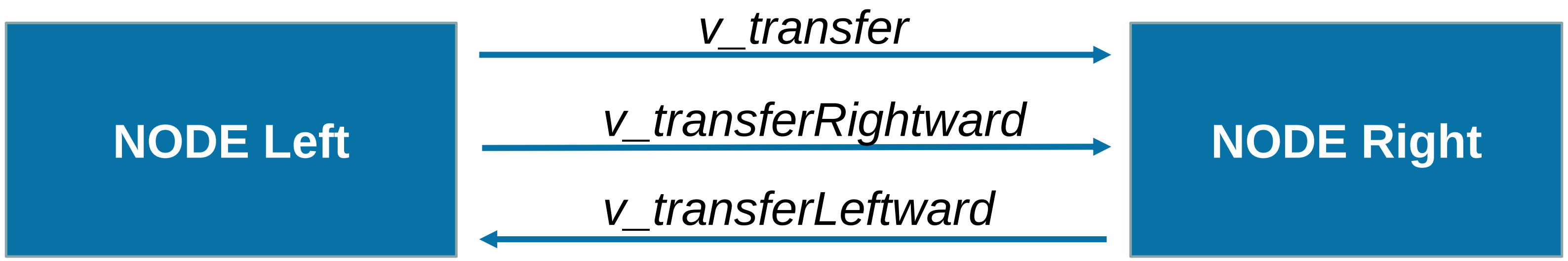
- **Transfers** between nodes are defined in "**nodeNode sheet**"
  - Both nodes have to be from the same grid
  - Existing transfer links can have different capacity to different direction
  - Future investments will always have equal capacity to both directions

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	grid	node1	node2	cap.rightward (MW)	cap.leftward (MW)	invested capacity (MW)	max invest (MW)	loss	inv.cost/kW	lifetime	interest	annuity	HVDC	color in results
2	elec	nodeA	nodeB	150	150		0	0.01	100	50	0.08	0.082	0	
3	elec	nodeB	nodeC	100	100		0	0.01	100	50	0.08	0.082	0	

nodeNode sheet

Transfers, 2/2

- **Transfer with losses** requires at least two variables
  - A linear equation with 'loss x transfer' would mean that in the other direction loss is actually a gain
- The loss can be used to make the **model 'leak'**
  - Instead of curtailing VRE, the model can dissipate energy by transferring in two directions at once
  - Can be controlled only with a binary variable (not allowed in FlexTool)
- Hence, **three variables**: transfer, transfer rightward and transfer leftward
  - Transfer does not contain loss
  - Transfer rightward allows losses and helps to limit the leakage
  - Transfer leftward helps to limit the leakage further

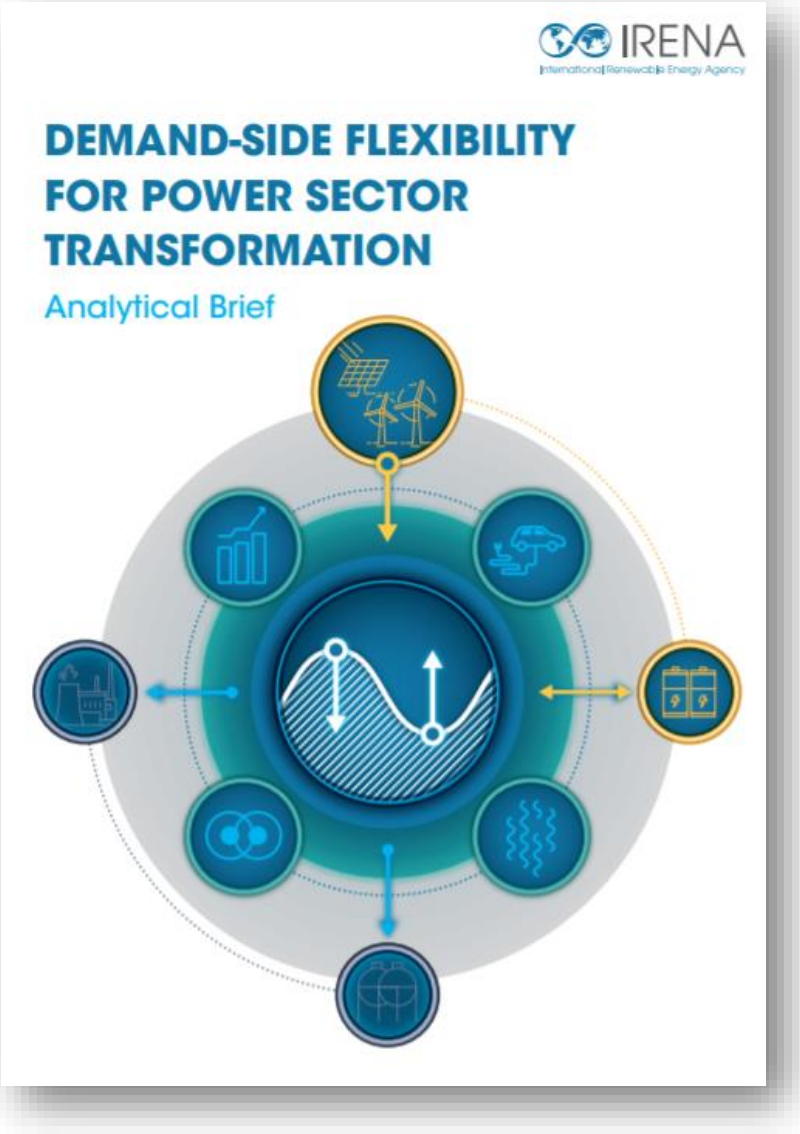


Demand response

Demand-side flexibility for power sector transformation

	Industrial	Commercial	Residential
Power-to-heat	●	●	●
Power-to-hydrogen	●	○	○
Electric vehicles	○	●	●
Smart appliances	○	●	●
Industrial processes	●	○	○

● The solution would be competitive/suitable in that end-use sector
○ The solution is unlikely to be competitive/suitable in that end-use sector



Modeling demand response in the IRENA FlexTool

IRENA FlexTool

- Demand response is defined in "**unit_type**" sheet, as if it was a generator. Defined as:
  - **Demand response increase** – Generator with negative price and empty charging efficiency
  - **Demand response downwards** – Generator with positive price and efficiency

unit type	efficiency	min load	eff at min load	ramp up (p.u. per min)	ramp down (p.u. per min)	O&M cost/MWh	availability	max reserve	inertia constant (MWs/MW)	fixed cost/kW/year	inv.cost/kW	inv.cost/kWh	fixed kW/kWh ratio	conversion eff	startup cost	min uptime (h)	min downtime (h)	eff charge	self discharge loss	lifetime	interest	annuity	non synchronous
demand_incr				1.00	1.00	-15.0	1.00	1.00										1.00		10	0.08	0.149	0
demand_decr	1.00			1.00	1.00	100.0	1.00	1.00												10	0.08	0.149	0

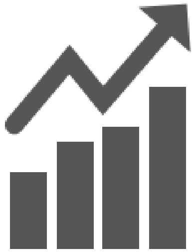
- In "**units**" sheet the following is defined:
  - Capacity (MW) – If the demand response is an increase then negative maximum capacity and if it is to decrease then positive

		Choose one input option (none, fuel, cf profile, inflow **or** input grid+node)					Output #1		
unitGroup	unit type	fuel	cf profile	inflow	input grid	input node	output grid	output node	capacity (MW)
Dem_inc	demand_incr						elec	nodeC	-30
Dem_dec	demand_decr						elec	nodeC	40

Power-to-heat

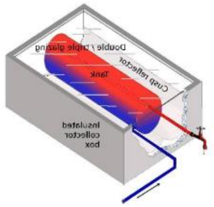
Modelling Power-to-heat in IRENA FlexTool

Heat Grid



Demand

- Defined demand profile in “ts_energy” sheet
- This demand would represent heat demand in system



Thermal Storage

- Defined exactly the same as electricity storage but in heat grid (see slides on electricity storage)
- Usually use the property: “self-discharge loss”

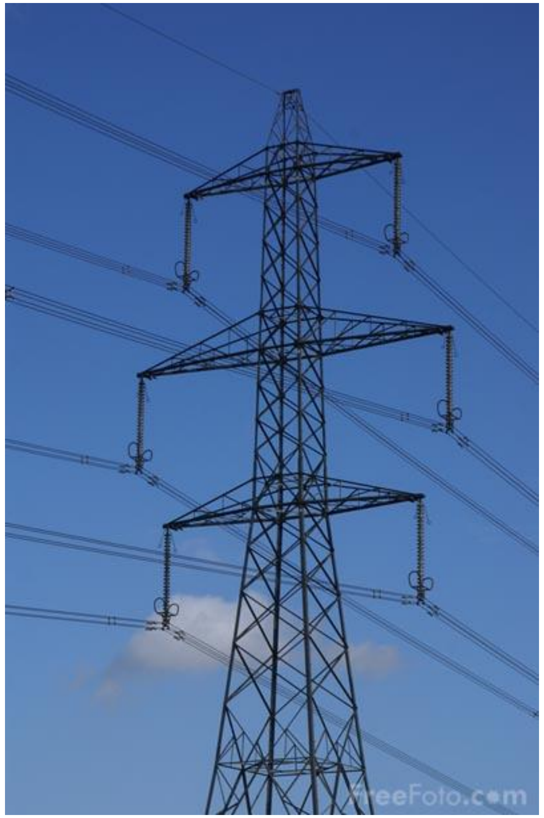
Direct heat devices

- Defined exactly the same as a generator but in heat grid (see slides on generators)
- Examples: solar thermal, gas boilers, etc.

Power-to-heat devices

(NEXT SLIDE)

Electricity Grid



Power-to-heat devices in IRENA FlexTool

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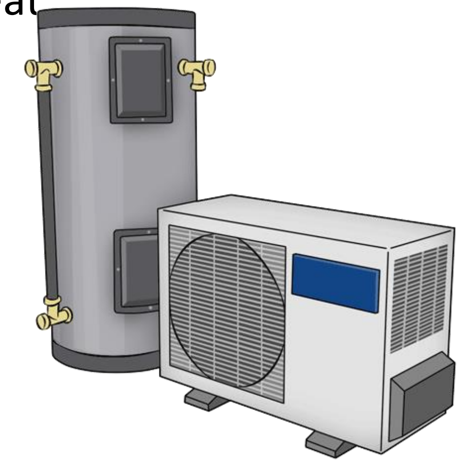
- Power-to-heat devices can be heat pumps or electric boilers that convert electricity to heat
- Defined similar to generators with some peculiarities:
  - Static efficiency – Defined directly in “unit_type” sheet as “conversion_eff”

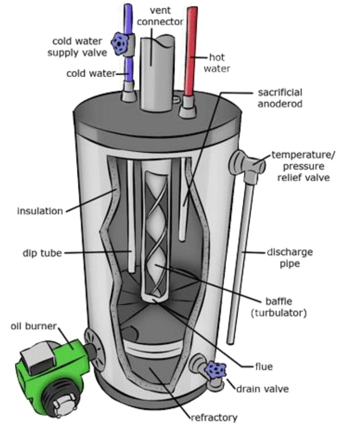


unit type	efficiency	min load	eff at min load	ramp up (p.u. per min)	ramp down (p.u. per min)	O&M cost/MWh	availability	max reserve	inertia constant (MWs/MW)	fixed cost/kW/year	inv.cost/kW	inv.cost/kWh	fixed kW/kWh ratio	conversion eff	startup cost	min uptime (h)	min downtime (h)	eff charge	self discharge loss	lifetime	interest	annuity	non synchronous
heat_pump				1.00	1.00		1.00	0.50			1000			2.50						40	0.08	0.084	1

  - Dynamic efficiency – Activate option in “units” sheet and then define it in “ts_unit” sheet

use efficiency time series	fix unit generation	use_min_generation	use_max_generation	use_min_online	inflow multiplier
			1	1	
1					

	grid	heat
	node	heatA
	unit	heat_pump
	unit_ts_param	efficiency
Time		
t0000		2.50
t0001		2.60
t0002		2.70
t0003		2.80
t0004		2.90
t0005		3.00

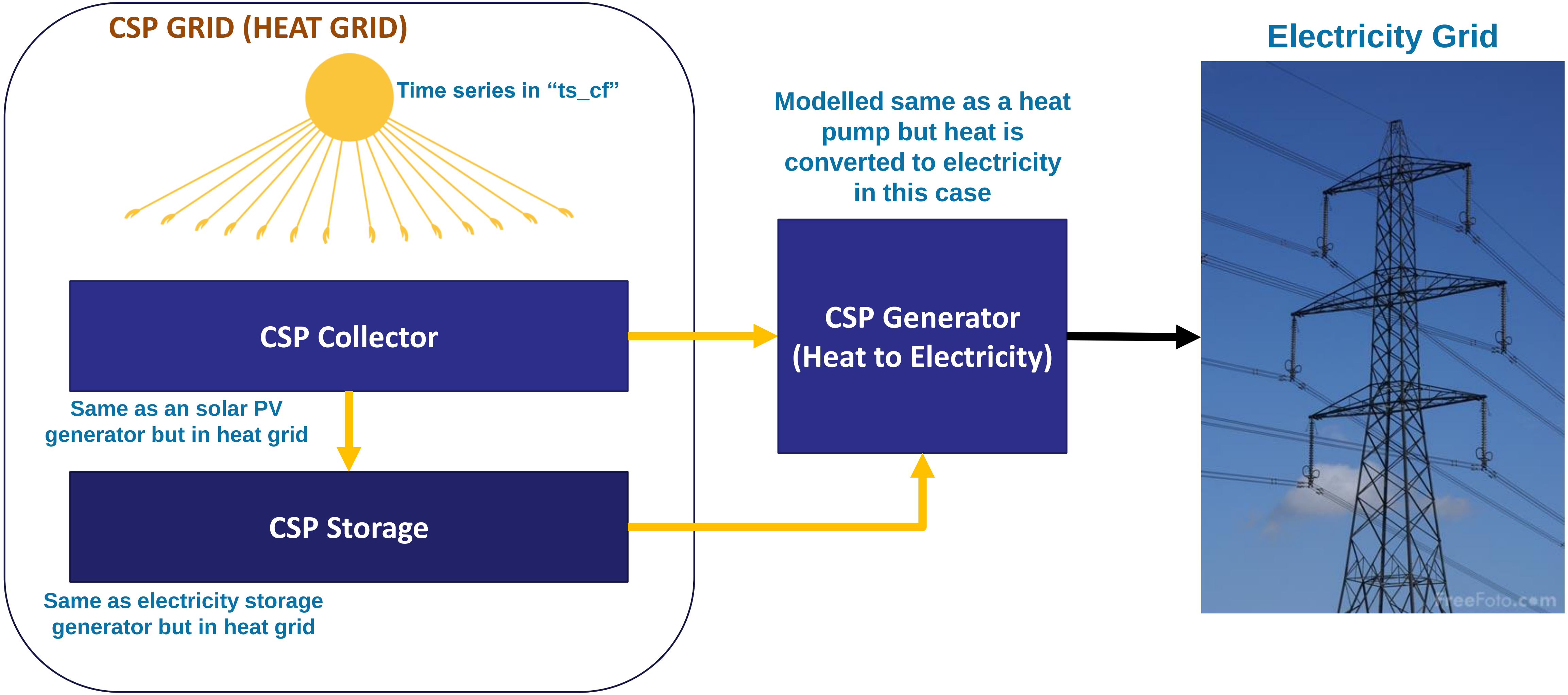


- **IMPORTANT**: Define electricity as input grid and heat as output grid in the “units” sheet

Concentrated Solar Power (CSP)

Modelling CSP units in FlexTool

- CSP is represented in the FlexTool as an additional single node grid with zero demand
- The CSP grid is interconnected with electrical grid at a specific node



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