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
Electricity Storage
Electricity Storage Valuation Framework

Phase 01
- Identify electricity storage services to support the integration of VRE

Phase 02
- Map storage technologies with identified services

Phase 03
- Analyse the system value of electricity storage compared to alternative flexibility options

Phase 04
- Simulate storage operation and stacking of revenue

Phase 05
- Assess the viability of the storage project
Modeling electricity storage in IRENA FlexTool

- 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

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

<table>
<thead>
<tr>
<th>unit type</th>
<th>inv. cost/kW</th>
<th>inv. cost/kWh</th>
<th>fixed kW/kWh ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>battery</td>
<td>80</td>
<td>1.000</td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>unit type</th>
<th>inv. cost/kW</th>
<th>inv. cost/kWh</th>
<th>fixed kW/kWh ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>battery</td>
<td>20</td>
<td>80</td>
<td></td>
</tr>
</tbody>
</table>
Smart Charging of Electric Vehicles

EVs’ batteries can provide flexibility to the power system.

A flexible power system can integrate more VRE and charge EVs with more RE.

VRE decarbonize the transport sector.

EVs decarbonize the power 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

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

- 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

Electricity Grid

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

\[ P_{tot} = \alpha \times \sum P_{Chargers} \]
\[ E_{tot} = \alpha \times \sum E_{battery} \]

\[ \alpha = \text{Simultaneity factor} \]

Discharge

Charge

Ancillary services
Power-to-hydrogen
Green hydrogen for the energy transition
Modelling Power-to-hydrogen in IRENA FlexTool

**Hydrogen Grid**

- Defined demand profile in “ts_energy” sheet
- This demand would represent hydrogen demand in the system
- 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
- In hydrogen grid other methods of hydrogen production can also be modelled in a simplified way
- Examples: steam methane reforming (SMR)

**Electricity Grid**

- Electrolyser (NEXT SLIDE)
- Fuel Cell (NEXT SLIDE)
Electrolysers and Fuel Cells

- 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

- **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
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

<table>
<thead>
<tr>
<th></th>
<th>Industrial</th>
<th>Commercial</th>
<th>Residential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power-to-heat</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power-to-hydrogen</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electric vehicles</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smart appliances</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industrial processes</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- 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

- 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

- 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
Power-to-heat
Modelling Power-to-heat in IRENA FlexTool

**Heat Grid**

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

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

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

**Electricity Grid**

- Power-to-heat devices
  (NEXT SLIDE)
Power-to-heat devices in IRENA FlexTool

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

**IMPORTANT**: Define electricity as input grid and heat as output grid in the “units” sheet.
Concentrated Solar Power (CSP)
CSP is represented in the FlexTool as an additional single node grid with zero demand. The CSP grid is interconnected with the electrical grid at a specific node.

- CSP Collector: Same as a solar PV generator but in the heat grid.
- CSP Storage: Same as an electricity storage generator but in the heat grid.
- CSP Generator (Heat to Electricity): Modelled same as a heat pump but heat is converted to electricity in this case.