Electrification of a Chemicals plant

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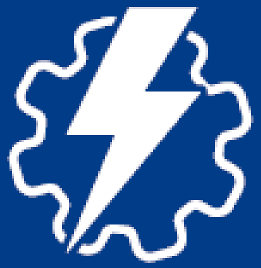
To be used if the SKY 1.5 scenario is discussed or mentioned in the disclosed materials

This [report] contains data and analysis from Shell's Sky 1.5 scenario. Shell Scenarios are not intended to be projections or forecasts of the future. Shell scenarios including the scenarios contained in the [Report/Booklet/Video/Presentation] are not Shell's strategy or business plan. When developing Shell's strategy, our scenarios are one of many variables that we consider. Ultimately, whether society meets its goals to decarbonize is not within Shell's control. While we intend to travel this journey in step with society, only governments can create the framework for success. The Sky 1.5 scenario starts with data from Shell's Sky scenario, but there are important updates. First, the outlook uses the most recent modelling for the impact and recovery from COVID-19 consistent with a Sky 1.5 scenario narrative. Second, it blends this projection into existing Sky (2018) energy system data by around 2030. Third, the extensive scaleup of nature-based solutions is brought into the core scenario, which benefits from extensive new modelling of that scale-up. (In 2018, nature-based solutions required to achieve 1.5°C above pre-industrial levels by the end of this century were analysed as a sensitivity to Sky. This analysis was also reviewed and included in the IPCC Special Report on Global Warming of 1.5°C (SR15).) Fourth, our new oil and natural gas supply modelling, with an outlook consistent with the Sky 1.5 narrative and demand, is presented for the first time. Fifth, the Sky 1.5 scenario draws on the latest historical data and estimates to 2020 from various sources, particularly the extensive International Energy Agency energy statistics. As with Sky, this scenario assumes that society achieves the 1.5°C stretch goal of the Paris Agreement. It is rooted in stretching but realistic development dynamics today but explores a goal-oriented way to achieve that ambition. We worked back in designing how this could occur, considering the realities of the situation today and taking into account realistic timescales for change. Of course, there is a range of possible paths in detail that society could take to achieve this goal. Although achieving the goal of the Paris Agreement and the future depicted in Sky 1.5 while maintaining a growing global economy will be extremely challenging, today it is still a technically possible path.

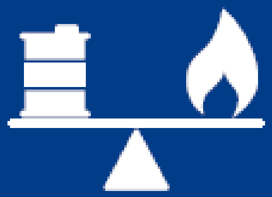
Main take away

LEVERAGE ELECTRIFCATION OVER CONVENTIONAL



Due to increased safety, higher availability, reduced maintenance, a more uniform heat flux.

FUEL & GAS BALANCE

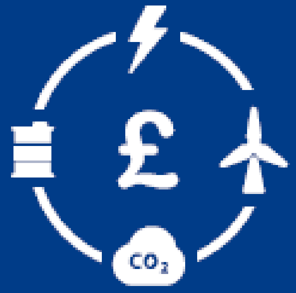


Establish waste to product value chains to replace the low value waste stream (currently used as fuels) with renewable power sources.

UPGRADES TO ELECTRIC GRID INFRASTRUCTURE

Upgrade infrastructure of local grid to increase capacity.
Reduce the cost of grid infrastructure.
Brings resilience as national grids aim to decarbonise over time.

ENERGY COSTS



Electrification will become more cost effective as the cost of renewable power continues to decline.

GOVERNMENTAL CONDITIONS

Favorable conditions include CO_2 pricing, project subsidies, carbon intensity mandates, meeting SO_x & NO_x restrictions.

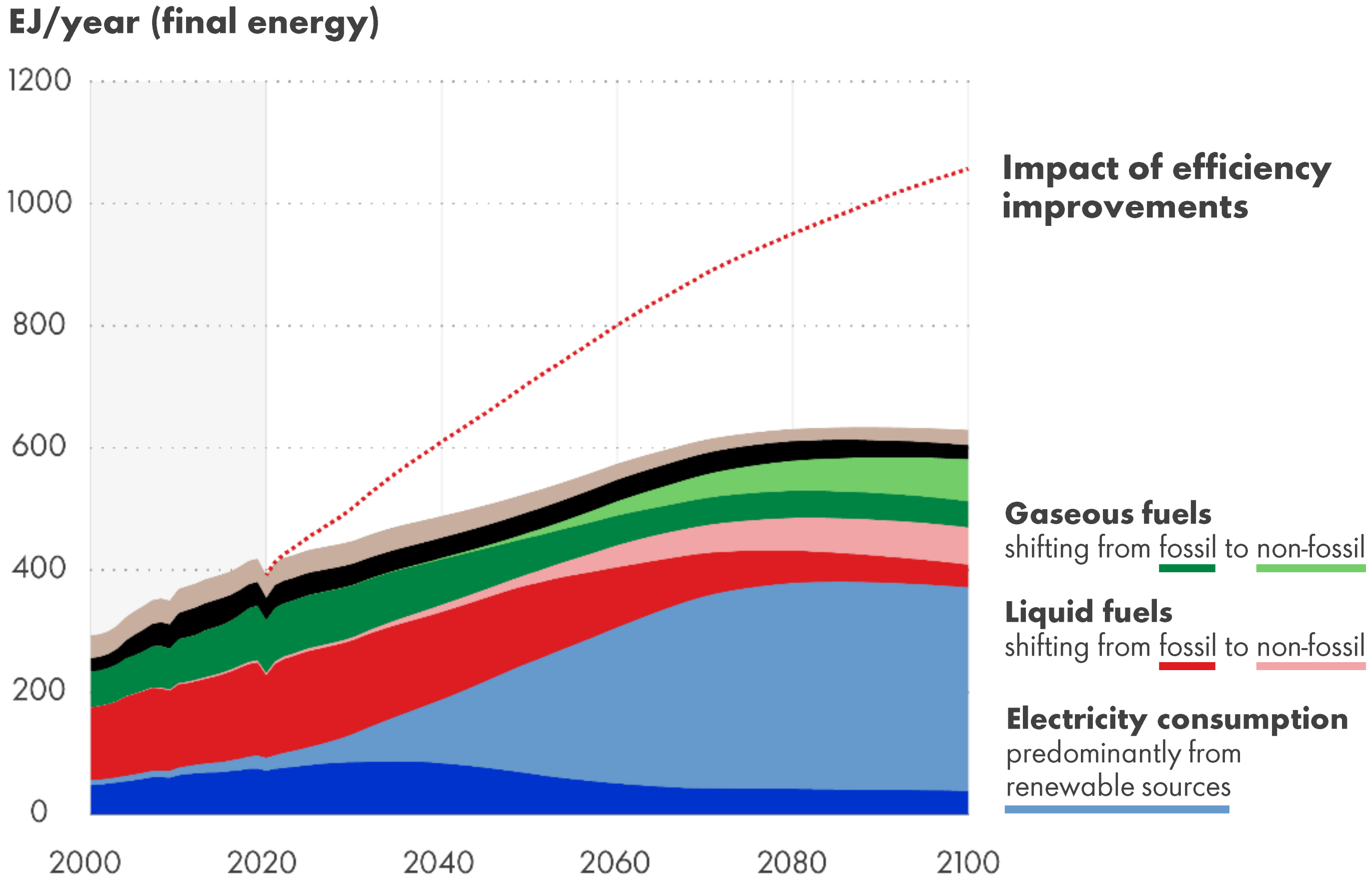
Agenda

- Electrification
  - Why
  - &Shell?
- Electrificaiton of a Chemical plants
  - Equipment electrification
  - Dilemma's

Why electrification - 5 COMMON ENERGY TRENDS ACROSS ALL OUTLOOKS

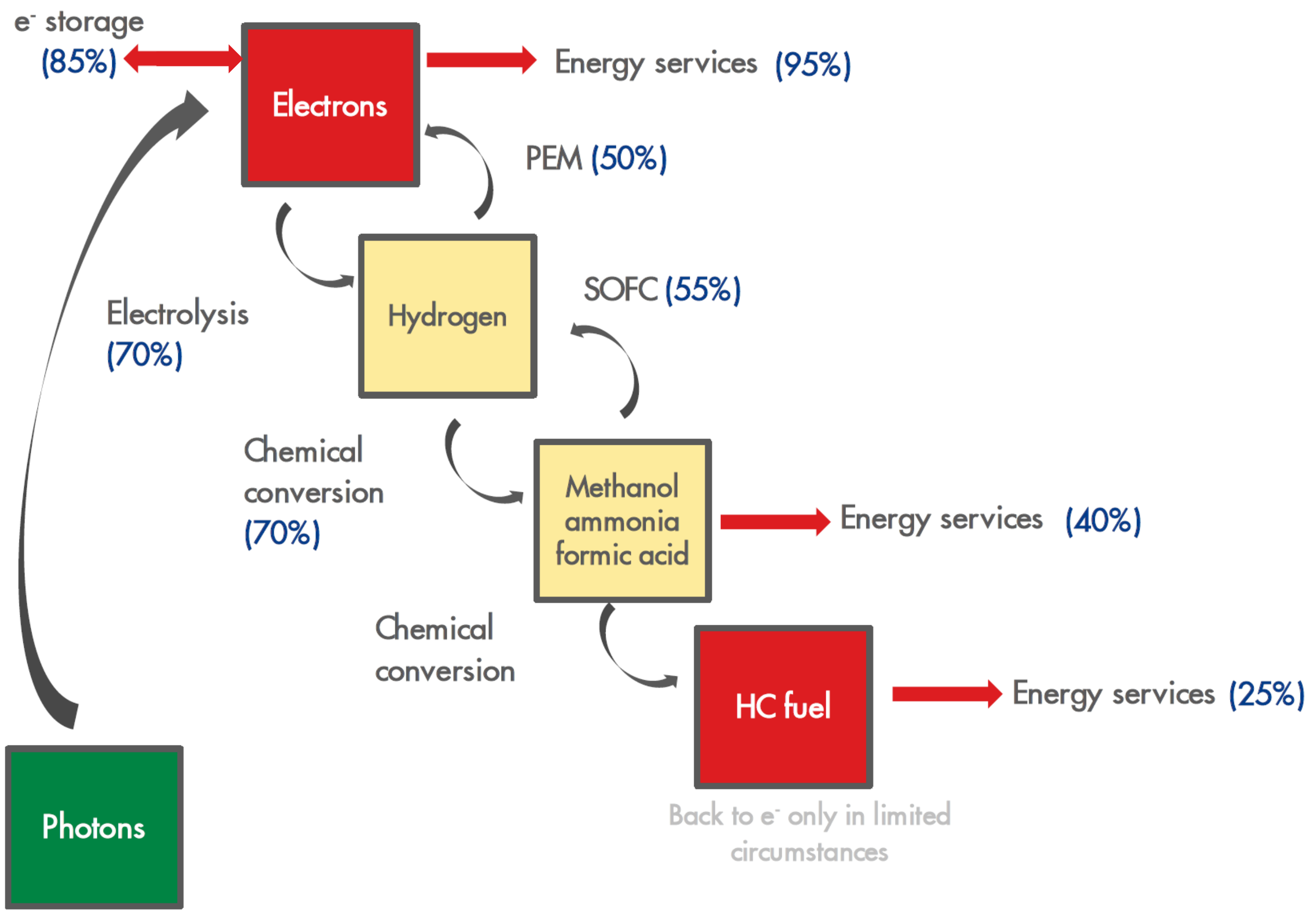
1. Growing energy needs and efficiency
2. Oil and natural gas remain important in key services
3. Emissions removal makes a contribution
4. Need for molecular fuels in hard-to-electrify sectors – increasingly decarbonised
5. Deep electrification from Renewable sources

Example: Total final consumption of energy – Sky 1.5 scenario



Why electrification - Direct usage of electricity most effective way to consume

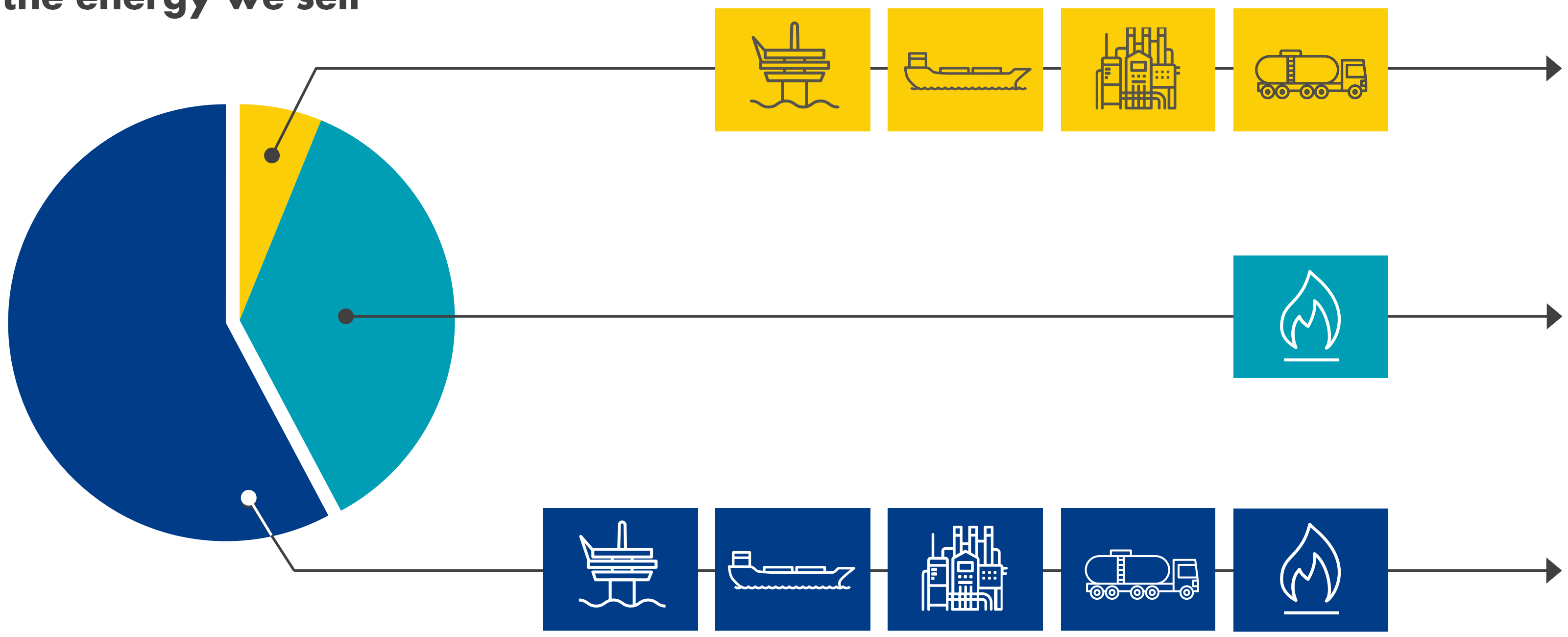
- Basic physics: electricity is high-quality energy
- Direct usage of electricity is the most cost-effective way to consume renewable electricity
- Every conversion step reduces lowers overal efficiency



Why Shell? - climate target

Shell's target is to become a net-zero emissions energy business by 2050, in step with society's progress in achieving the goal of the UN Paris Agreement on climate change.

We address all emissions from the energy we sell



SCOPE 1 & 2
Our operational emissions

SCOPE 3
Emissions from use of energy sold by Shell (own production)

SCOPE 3
Full lifecycle emissions from energy sold by Shell (produced by others)

We believe our total carbon emissions from energy sold peaked in 2018 at around 1.7 Gtpa

Net-zero emissions from own operations by 2050 or sooner

Aiming to be net-zero on all the emissions from the manufacture of all our products[1]

Ways to achieve the ambition

Energy efficiency
- Operational improvements
- Process optimisation
- Reducing flaring / venting / fugitives

Use of low-carbon energy
- Low- and zero-carbon electricity and steam
- Biofuels
- Hydrogen

Carbon sinks
- Carbon capture, utilisation & storage
- Nature-based solutions

Governance
- Potential GHG costs associated with operational GHG emissions
- Greenhouse gas energy management plans
- Performance standards or industry benchmarks for projects

[1] Refers to the Scopes 1 and 2 emissions in absolute terms associated with operations under direct Shell control

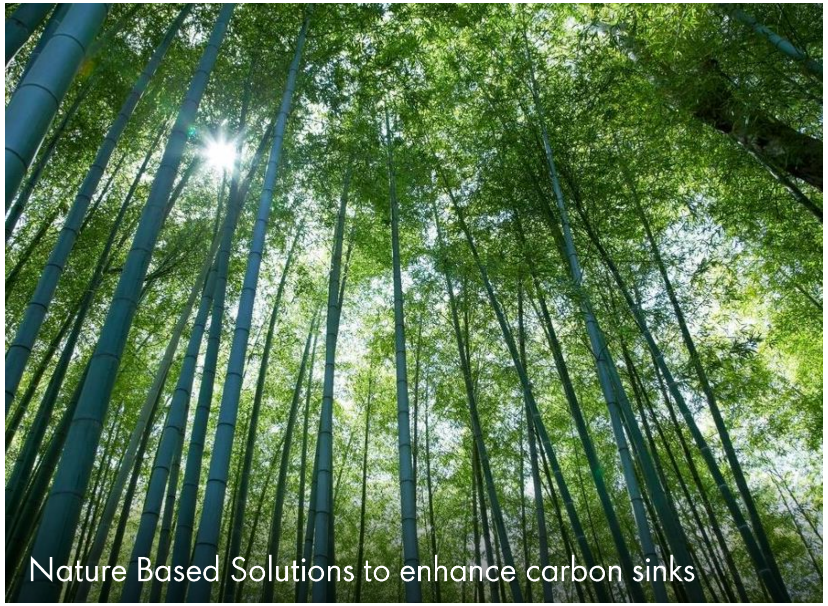
Driving low carbon energy supply and solutions

Specific themes to help accelerate the energy transition and adopting to evolving consumption patterns

Electrification of demand

Circularity in manufacturing of products

Hydrogen supply and use



Nature Based Solutions to enhance carbon sinks

SHELL AND THE ELECTRICITY SYSTEM

Investments and acquisitions

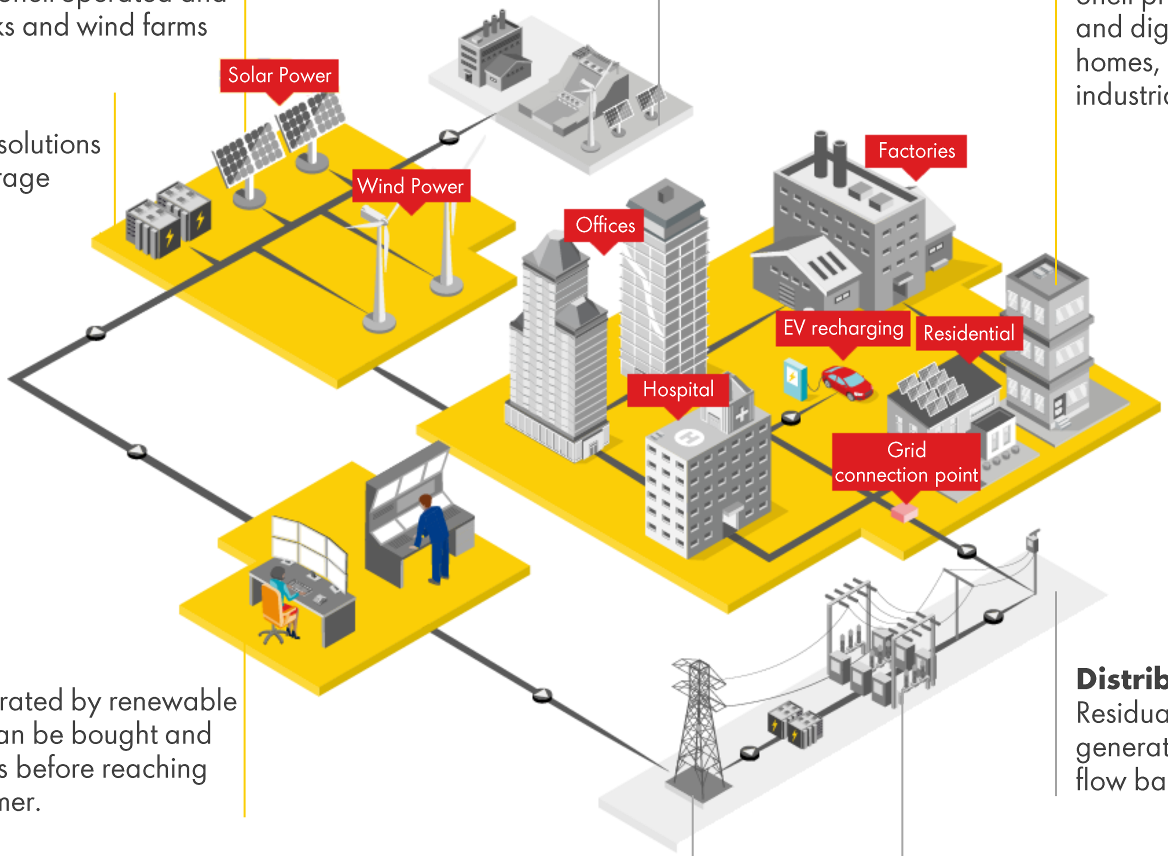
- Solar-konzept Italia, Italy, 2022
- Powershop, Australia, 2022
- Savion, USA, 2021
- Signed agreements to build 800 MW in the UK, 2021
- Inspire Capital, USA 2021
- Ubitricity, UK, 2021
- Next Kraftwerke, Germany, 2021
- Emerald floating wind project, Ireland, 2021
- Qabas solar plant, Oman, 2021
- Hollandse Kust (noord), 2020
- Gangarri, Australia, 2020
- Shell Energy (formerly ERM Power), Australia, 2019
- EOLFI, FR, 2019
- Hudson Energy, UK, 2019 (Shell Energy Retail)
- Limejump, UK, 2019
- sonnen, Germany, 2019
- Greenlots, USA, 2019
- First Utility, UK, 2018 (Shell Energy Retail)
- Borssele 3 and 4, Netherlands, 2018
- Silicon Ranch, USA, 2018
- Cleantech Solar, Singapore, 2018
- NewMotion, UK and Europe, 2017
- Shell Recharge, UK, 2017
- MP2 Energy, USA, 2017
- WonderBill, UK, 2015

Electricity production
Electricity produced by Shell-operated and non-operated solar parks and wind farms

Electricity storage
Surplus energy storage solutions such as grid battery storage

Power offtake
Energy Shell buys from third parties, including from solar, wind, hydro and gas power facilities

Customers
Shell provides energy and digital products to homes, businesses and industrial customers



Trading
Electricity generated by renewable power plants can be bought and sold many times before reaching the final consumer.

Distributed energy
Residual energy generated by customers flow back to the grid

Transmission networks
Transport electricity over distances

Distribution
Local distribution that carries low-voltage electricity to customers

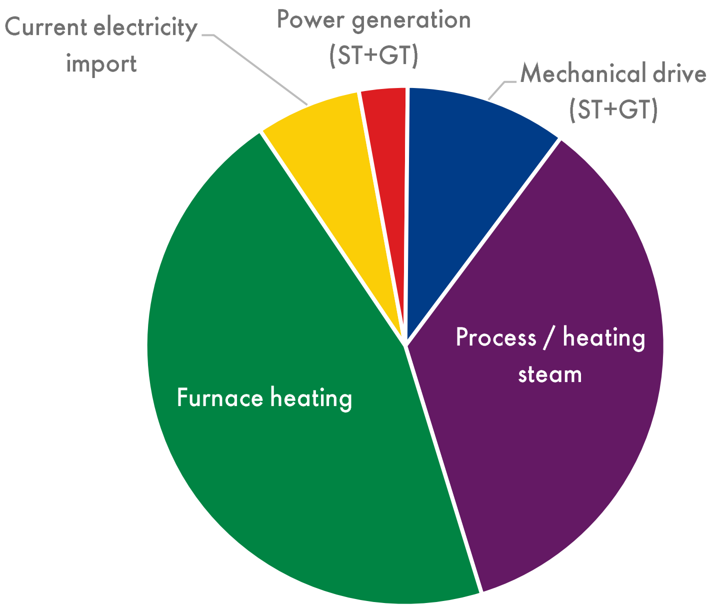
Electrification in a Chemical plant

LEVERAGE ELECTRIFCATION OVER CONVENTIONAL	FUEL & GAS BALANCE	UPGRADES TO ELECTRIC GRID INFRASTRUCTURE	ENERGY COSTS
Due to increased safety, higher availability, reduced maintenance, a more uniform heat flux.	Establish waste to product value chains to replace the low value waste stream (currently used as fuels) with renewable power sources.	Upgrade infrastructure of local grid to increase capacity. Reduce the cost of grid infrastructure. Brings resilience as national grids aim to decarbonise over time.	Electrification will become more cost effective as the cost of renewable power continues to decline.

Equipment - What can be electrified?

LEVERAGE ELECTRIFCATION OVER CONVENTIONAL

Energy use (example) – Chemical plant



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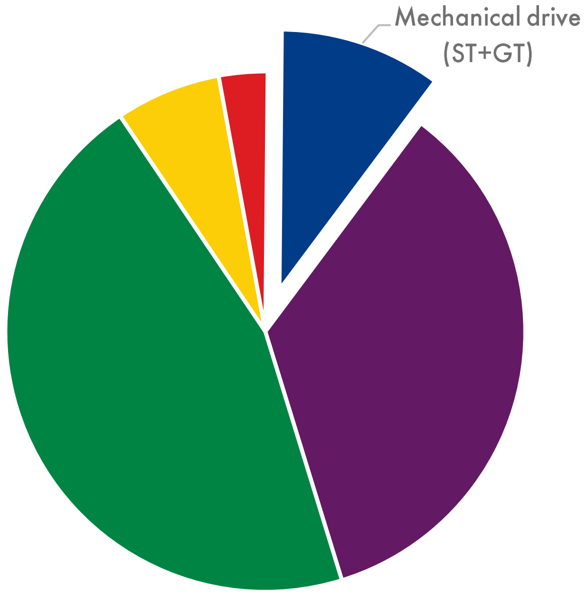
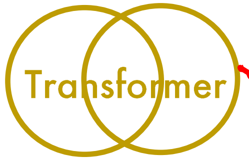


■ Mechanical drive → Electric motors



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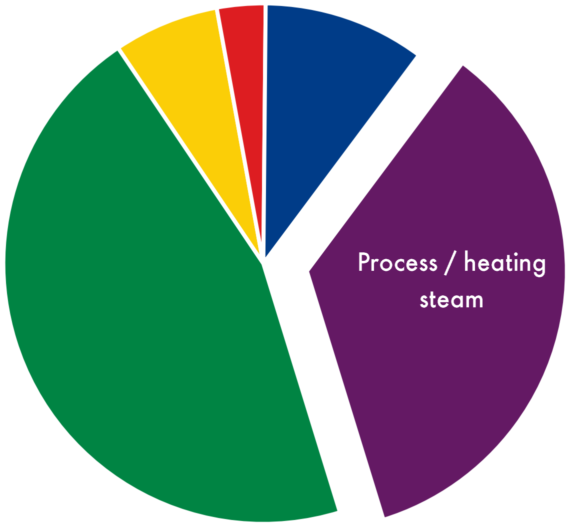
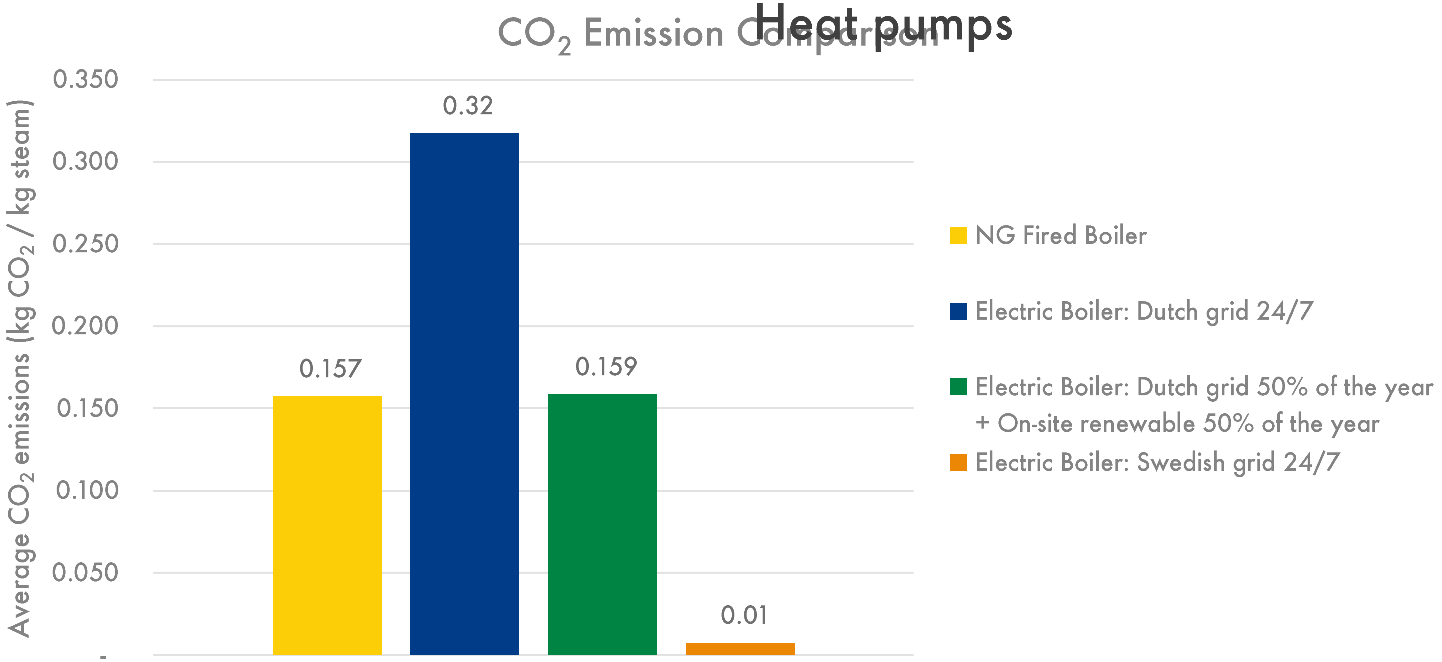


Gas boilers → Electrical boilers

Heat pumps



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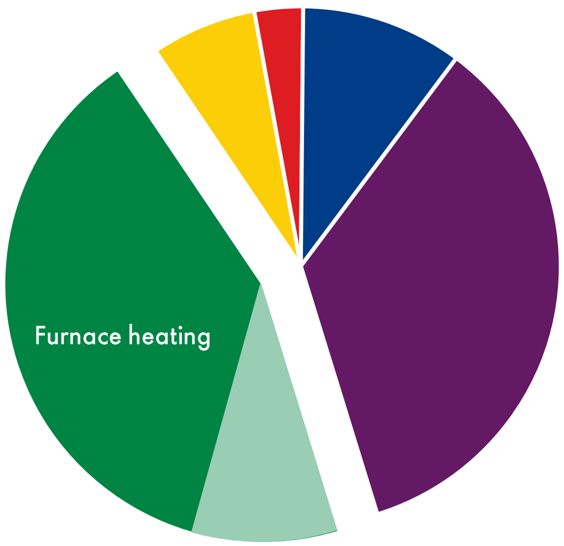

- Gas fired furnaces → electrical heaters
  - Different e-heaters types on the market
  - Applied for 1-phase non-fouling flows
  - Up to around 400 degC

LEVERAGE ELECTRIFCATION OVER CONVENTIONAL

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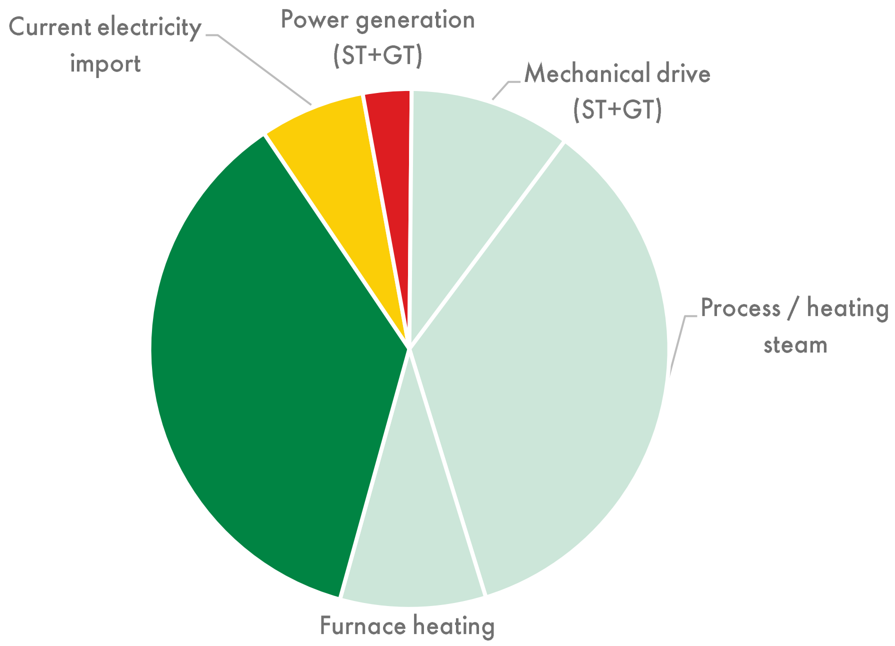
Energy use (example) – Chemical plant



Electrification opportunities

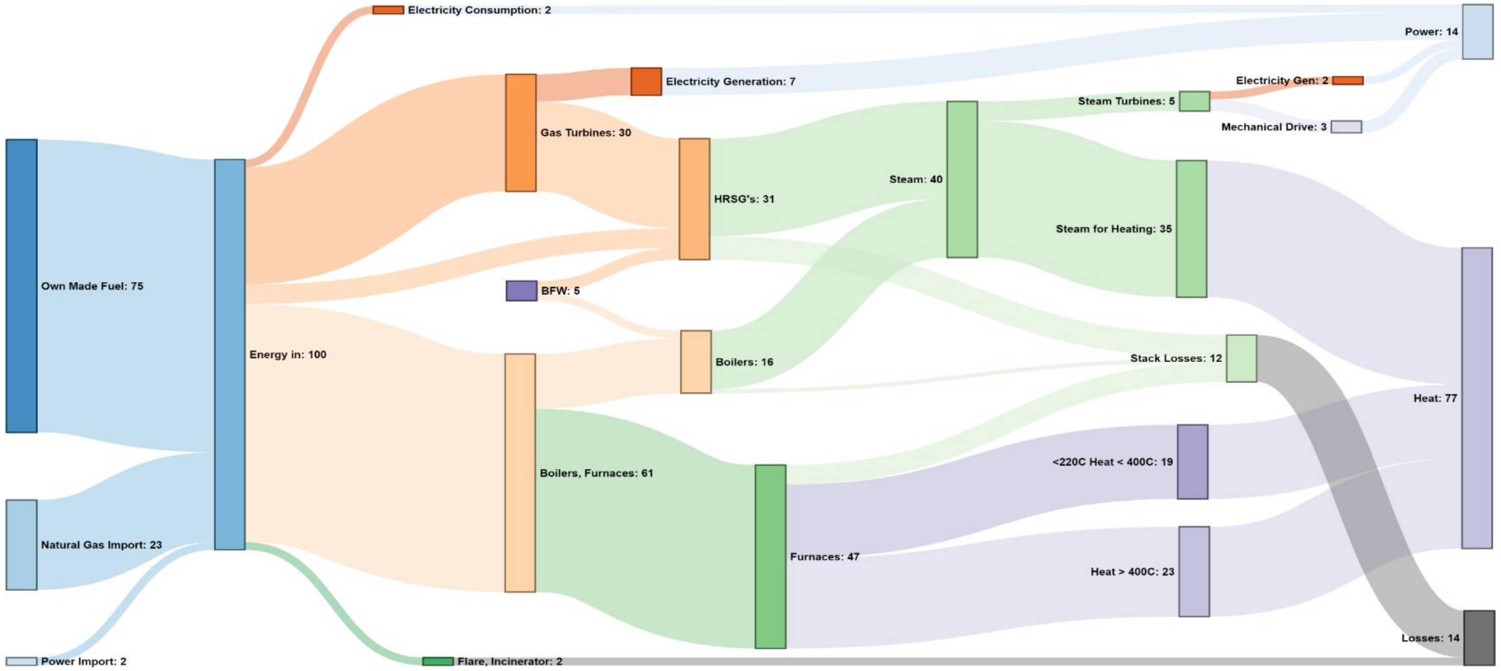
- License to operate
  - Achieving CO_2 and NO_x **emission reduction**
- Operational
  - Reduced **maintenance** (e-motors, e-heaters)
  - Increased **availability** (e-motors, e-heaters)
    - Run length, start / stop
  - Increased **safety** (e-heaters)
  - Increased **heat flux control** (e-heaters)
  - **Eliminating standby** heat load loads (e-heaters)

FUEL & GAS BALANCE

Electrification – Dilemma 1: Fuel and gas balance

Energy intake (example) – Chemical plant

Energy balance (example)



Electrification – Dilemma 1: Fuel and gas balance

FUEL & GAS BALANCE

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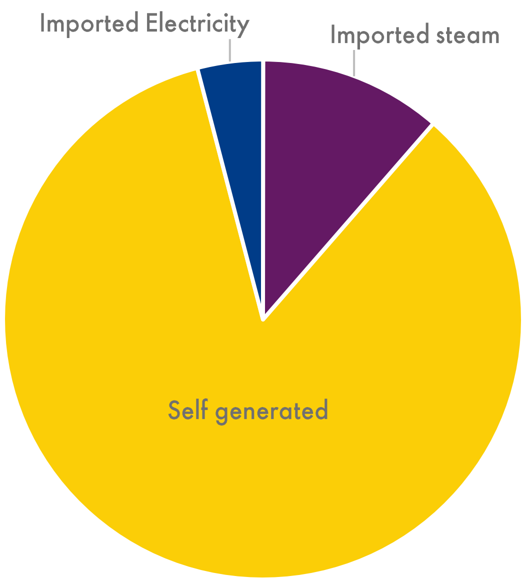
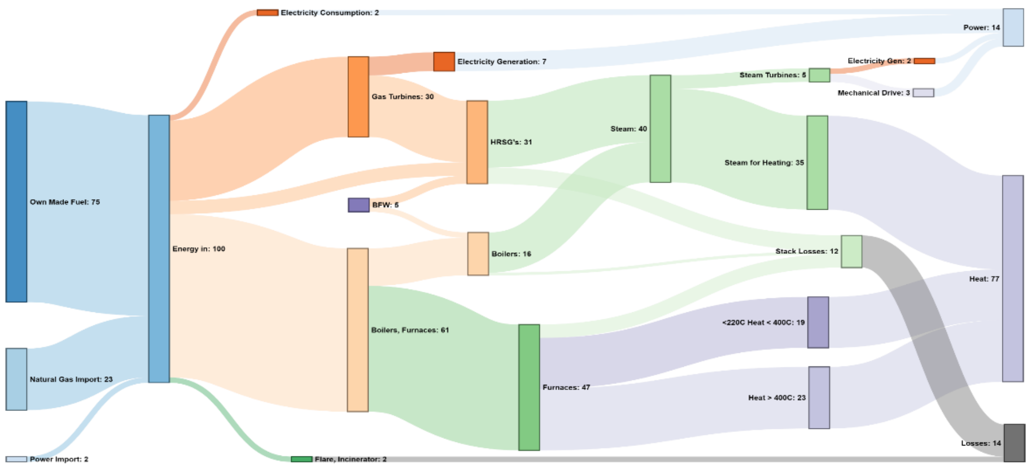


Energy balance (example)



Electrification – Dilemma 2: Electrical infrastructure cost

UPGRADES TO ELECTRIC GRID INFRASTRUCTURE

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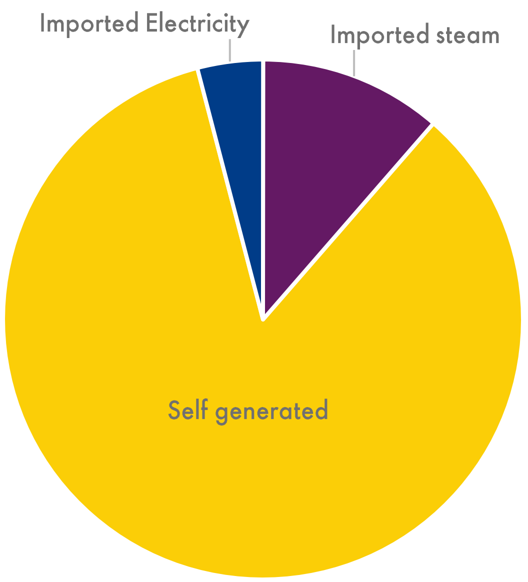


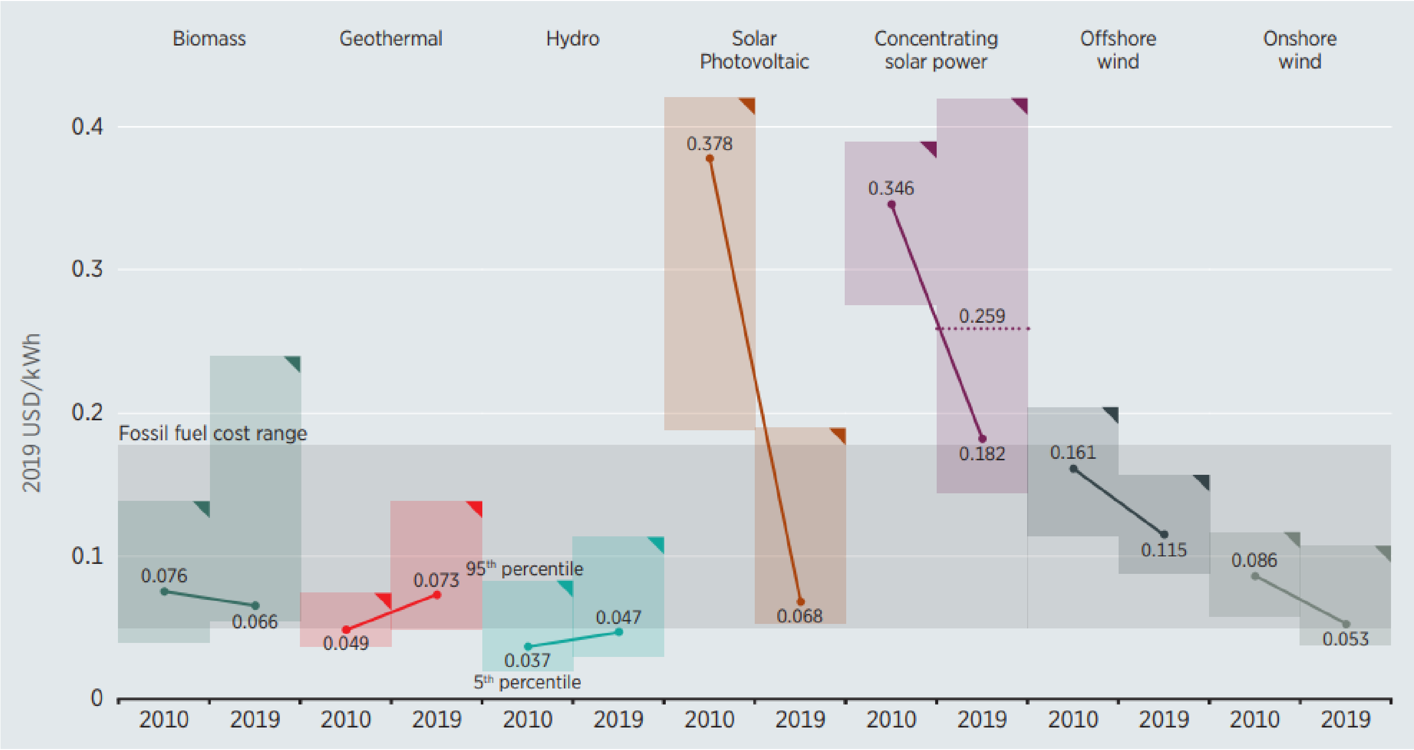
Cost depending on

- Small scale electrification:
  - Available spare capacity
- Large scale electrification
  - Greenfield / Brownfield deployment
  - Local availability of (renewable) power

Electrification – Dilemma 3: (Renewable) Power cost

- Renewable power cost or going down

  Not the whole story:
  - Capacity factor wind: ~30-50%
  - Capacity factor solar :~30%
- How much storage is required depends on:
  - Continuous / batch operation
  - Hybrid / full electrical



Source: Irena Power generation cost report 2019

Successful electrification depends on

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Q&A