

# Urban Energy Transitions

## Long-term spatial and temporal dynamics : case study of Paris

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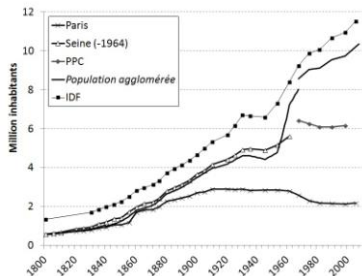
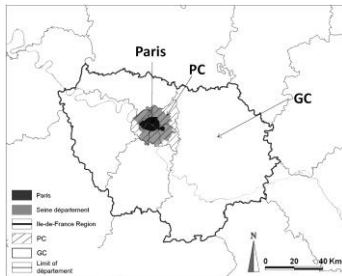
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### Overview

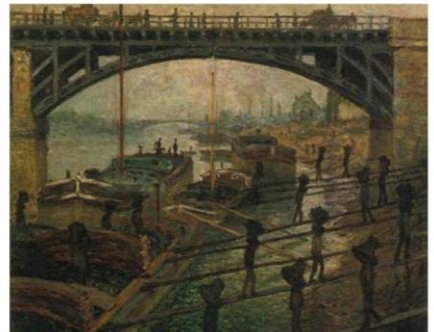
During the last two centuries, the energy regime shift from biomass to fossil energy changed remarkably the global environment. It is undeniable that urbanization was one of the important drivers of this historical process. From the 19<sup>th</sup> to the early 21<sup>st</sup> century, Paris has become one of major metropolitan cities in Europe and experienced industrialization, urban growth and the rise of its energy demand. Our research aims to understand local based socioecological trajectories and long-term energy transitions with Paris case study. To assess the urban energy demand, we used MEFA (Material and energy flow analysis) framework and included both urban fuel and draft animal feeds. During the 19<sup>th</sup> and 20<sup>th</sup> centuries, city's major resource changed from biomass to fossil and fissile combustibles. Biomass share in its energy demand fell from 100 % to almost zero. Its per capita total energy requirement grew from 30 to 140 GJ/cap/yr. The energy transitions changed fundamentally urban energy consumption pattern and extended city's supply area.

### Urban area extension in three steps



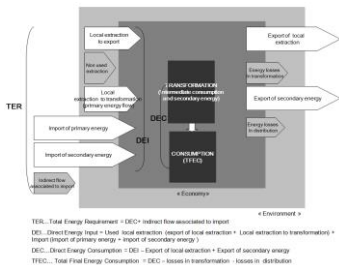
During the 19<sup>th</sup> and 20<sup>th</sup> centuries, Paris experienced population growth from 0.5 to 11 million inhabitants. Its urban area extended also in time: between 1870 and 1945 from Paris (historical urban center) to PPC (Paris dense agglomeration) and between 1945 and today from PPC to IDF region (including GC (urban periphery)).

↓ Fossil energy rose since 1800, firstly for heating and lightening then, after 1870, for mechanical power. After the WWII, city's total annual energy demand rose dramatically both by per capita energy demand increase and population growth.



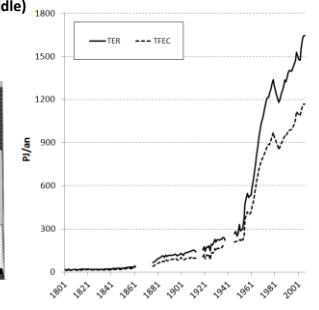
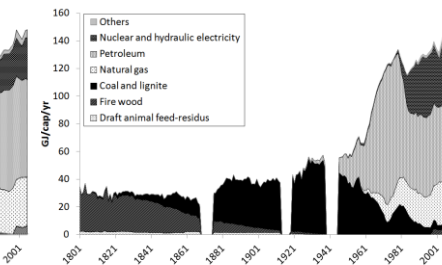
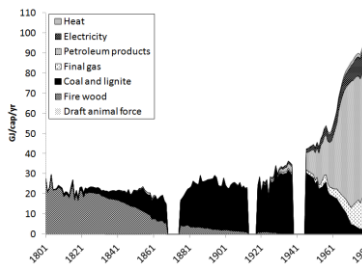
### Energy demand assessment with

#### Material and energy flow analysis framework



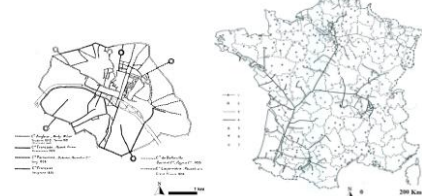
### Technical energy demand growth

Per capita energy use (left) and per capita energy demand (primary energy consumption)(middle) in GJ/cap/yr and total annual energy use(TFEC) and demand(TER) in PJ/yr (right)

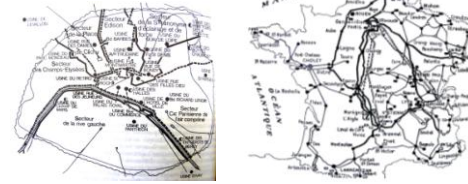


### Rise of technical energy systems and networked city

#### Gas network from 1836(left) to 1964(right)



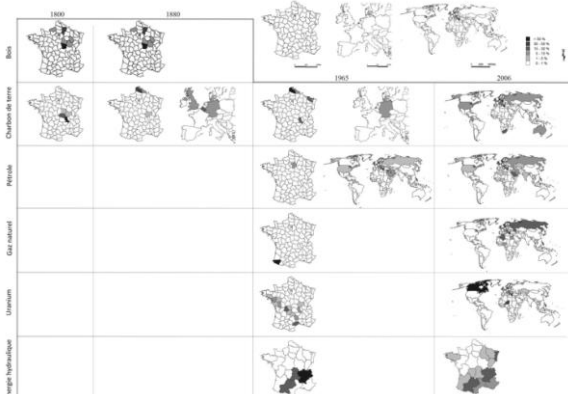
#### Electricity network from the late 19th century(left) to 1945(right)



Energy transitions was accompanied by the spatial diffusion of physical networks stimulated by the urbanization of the region. The spatial diffusion of manufactured gas (used for lighting and domestic heating) network contributed to market extension at regional scale since 1850. Residential development in the close suburban area (PC) was associated with the gas network extension and its consumption increase. Electricity consumption began at the late 19<sup>th</sup> century. Since the 1930s, electricity supply experienced new developments with the interconnection of the local network with other regions. Between 1930 and 1970, the regional electrification rate reached almost 100%. Regional consumption increased rapidly.

### Resource changes and city's supply area extension

Energy supply area of Paris changed considerably during the last two centuries.



Since the early 19<sup>th</sup> century, merchandise transportation system construction and renewal improved remarkably energy supply.



Waterway connected to Paris in Seine hydraulic basin in 1800, 1870 and 2007



Railway in France in 1837, 1850 and 1870

### Conclusion

During the 19<sup>th</sup> and 20<sup>th</sup> centuries, Paris energy use and demand have remarkably grown. This energy transitions occurred with different development stages : heating system change from firewood to coal visibly started at the turn of the 19<sup>th</sup> century. Merchandise and interregional transportation by rail, powered by coal, were developed from 1850. Steam engines for mechanical energy production were vastly used after the 1870s and specific electricity developed from the end of the 19<sup>th</sup> century. During the 20<sup>th</sup> century, the dramatic growth in petroleum direct (for fuels) and indirect (for electricity) consumption was the main reason of energy demand growth. This process involved also complete change in urban consumption pattern and in technical system for energy provision. This urban energy transitions occurred simultaneously with spatial reorganization and the extension of energy provision system.