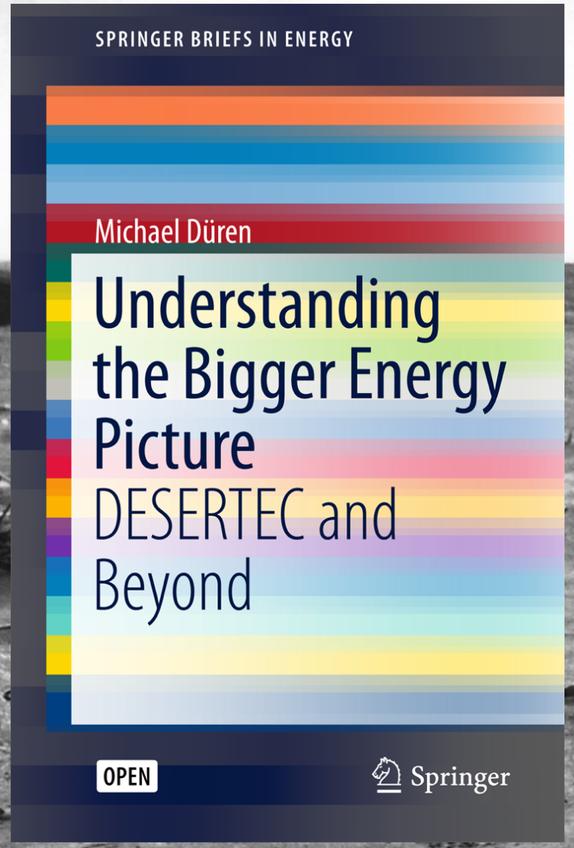
Die Auto-Bahn

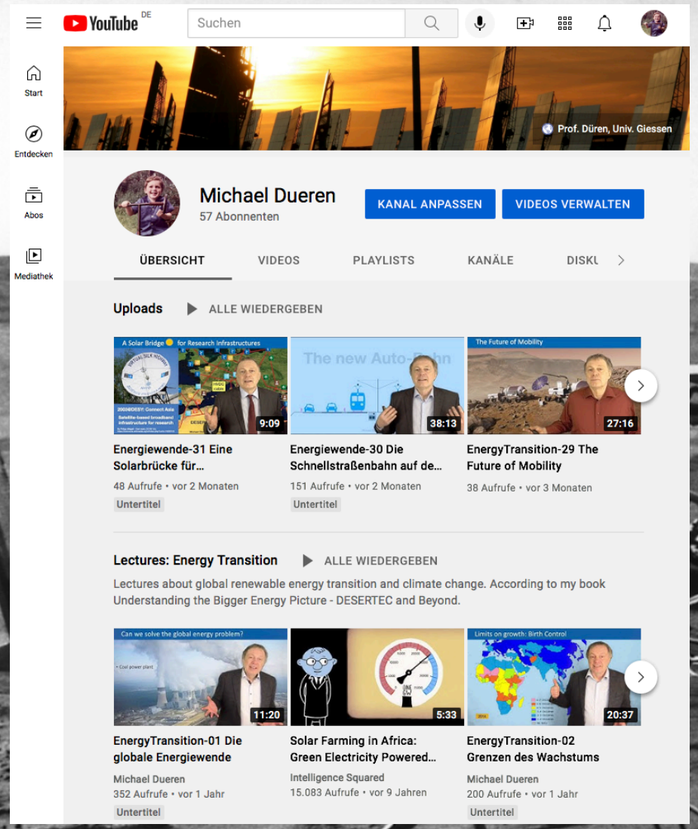
Nutzung der Automobilinfrastruktur für Schienenfahrzeuge

Arbeitskreis Energie der DPG, Bad Honnef, Oct. 21,2021

Michael Düren, Univ. Giessen

A Sustainable Future Model of Energy and Mobility





Book for free: https://dx.doi.org/10.1007/978-3-319-57966-5

Video Lectures for free: YouTube Channel: Michael Dueren

Physik Journal August/Sept. 2021

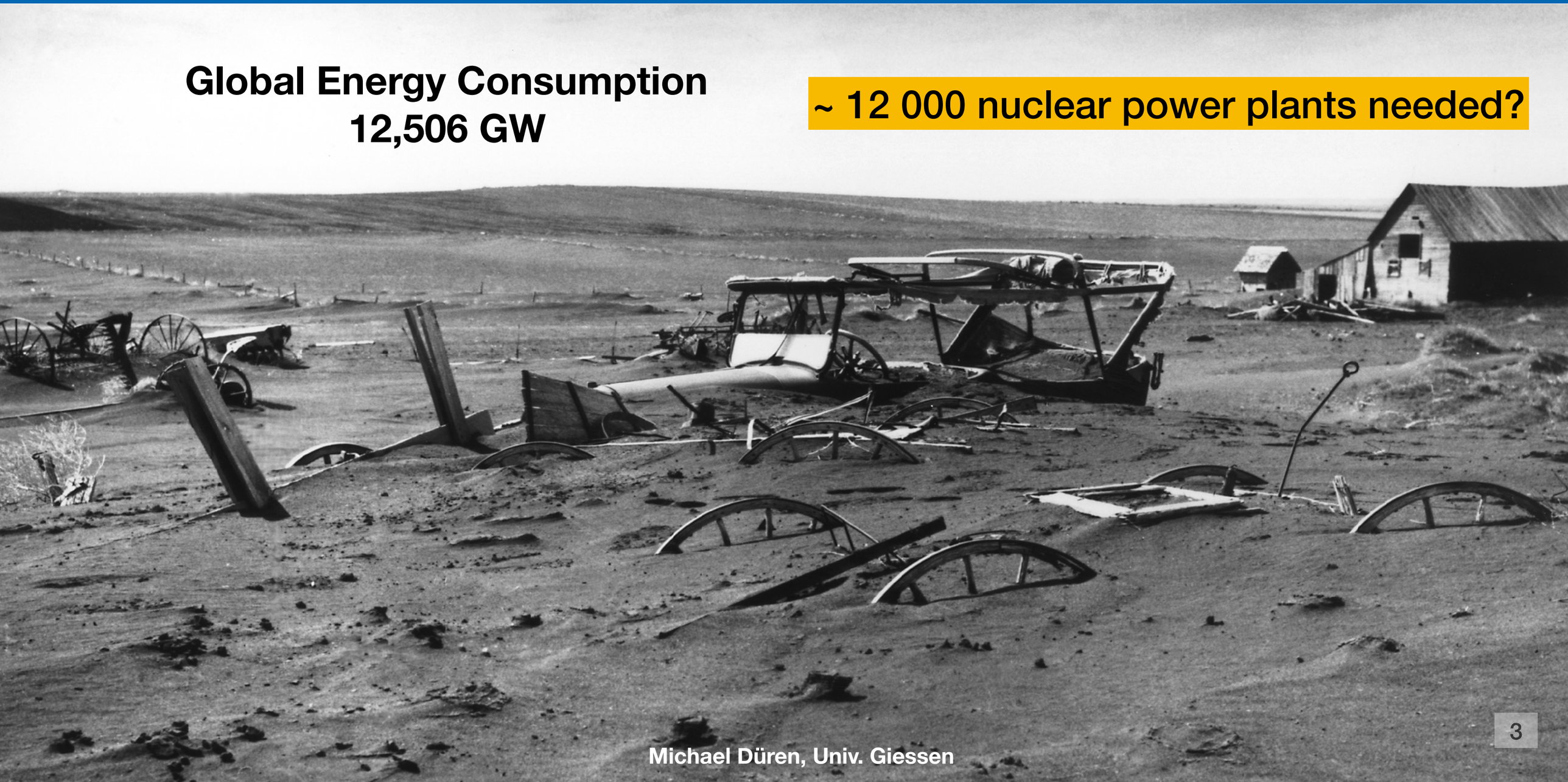
https://www.pro-physik.de/restricted-files/155228

Challenge of the World Energy Supply

YouTube
Lecture 3

Global Energy Consumption
12,506 GW

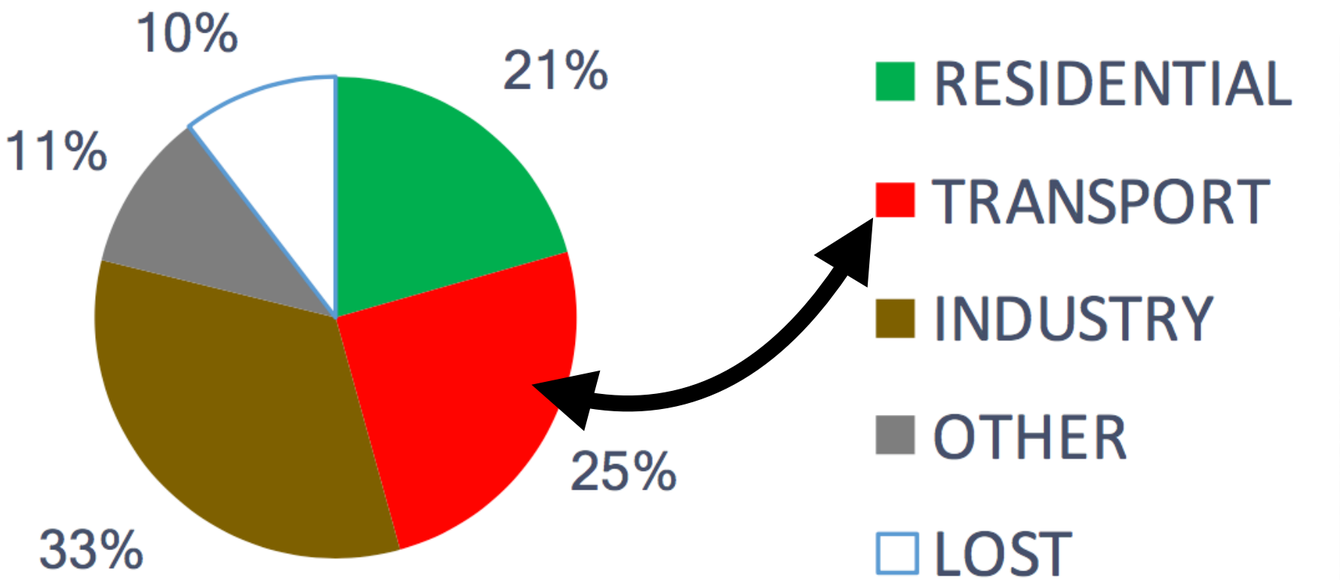
~ 12 000 nuclear power plants needed?



Challenge of the World Energy Supply

YouTube
Lecture 3

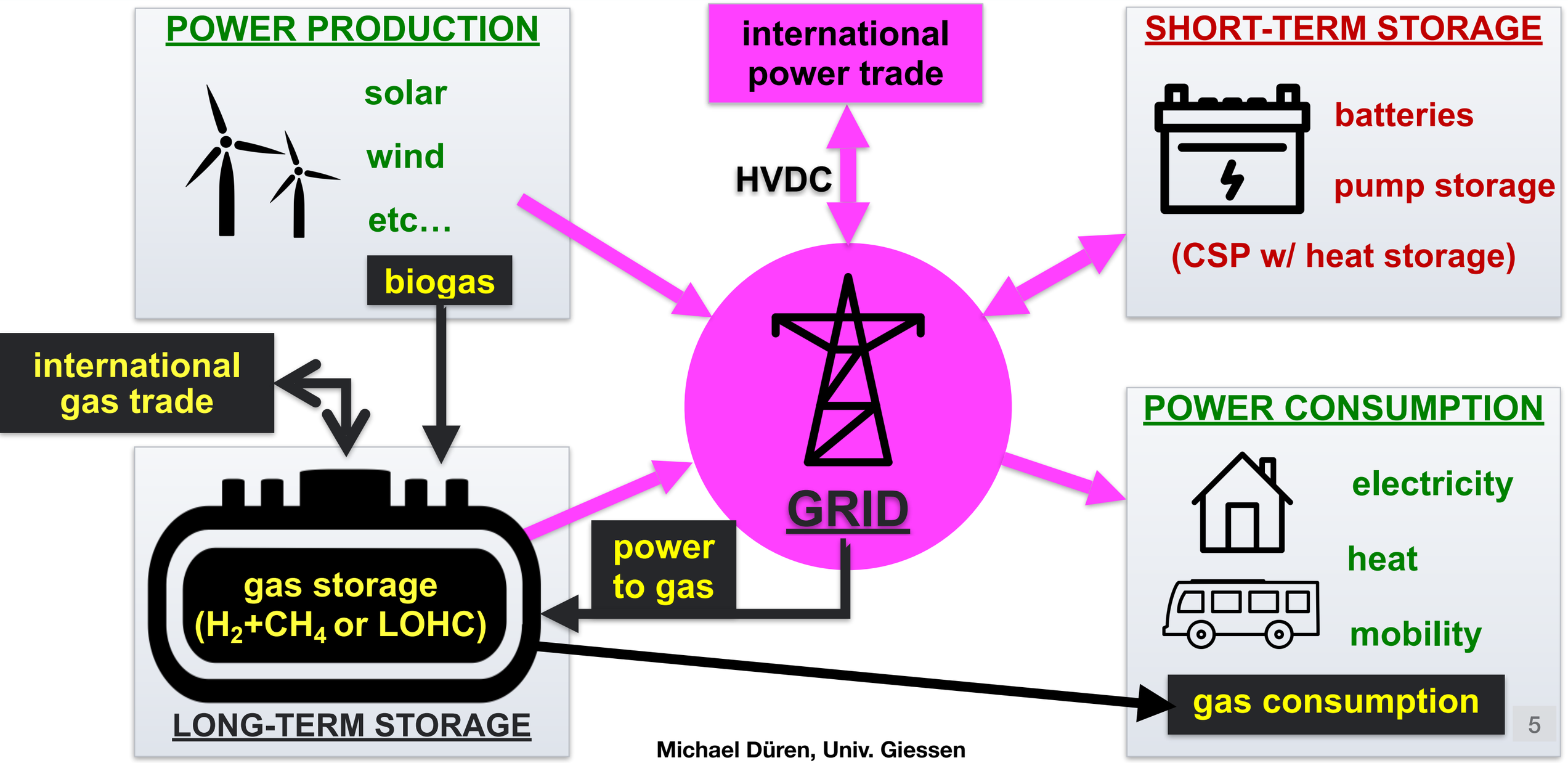
Global Energy Consumption
12,506 GW



~~~~ 12 000 nuclear power plants needed?
~~~~

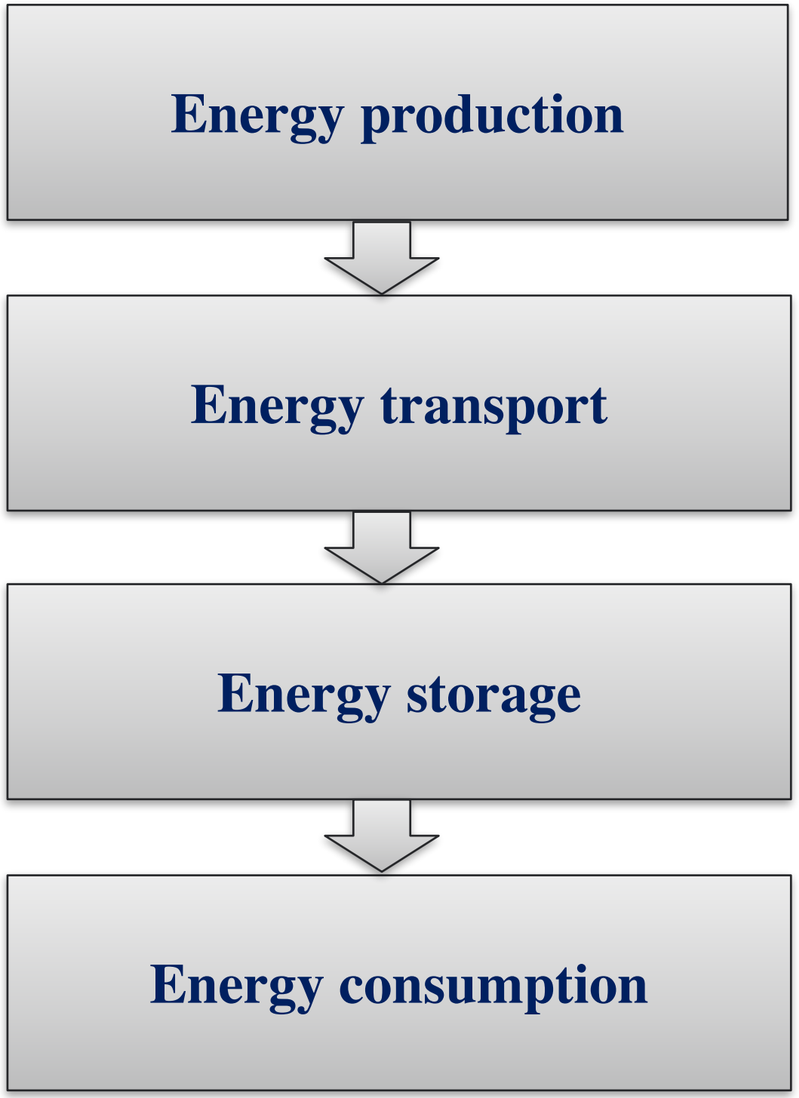
The Future Energy System

Deutsche Physikalische Gesellschaft DPG
PHYSIKonkret Nr. 48



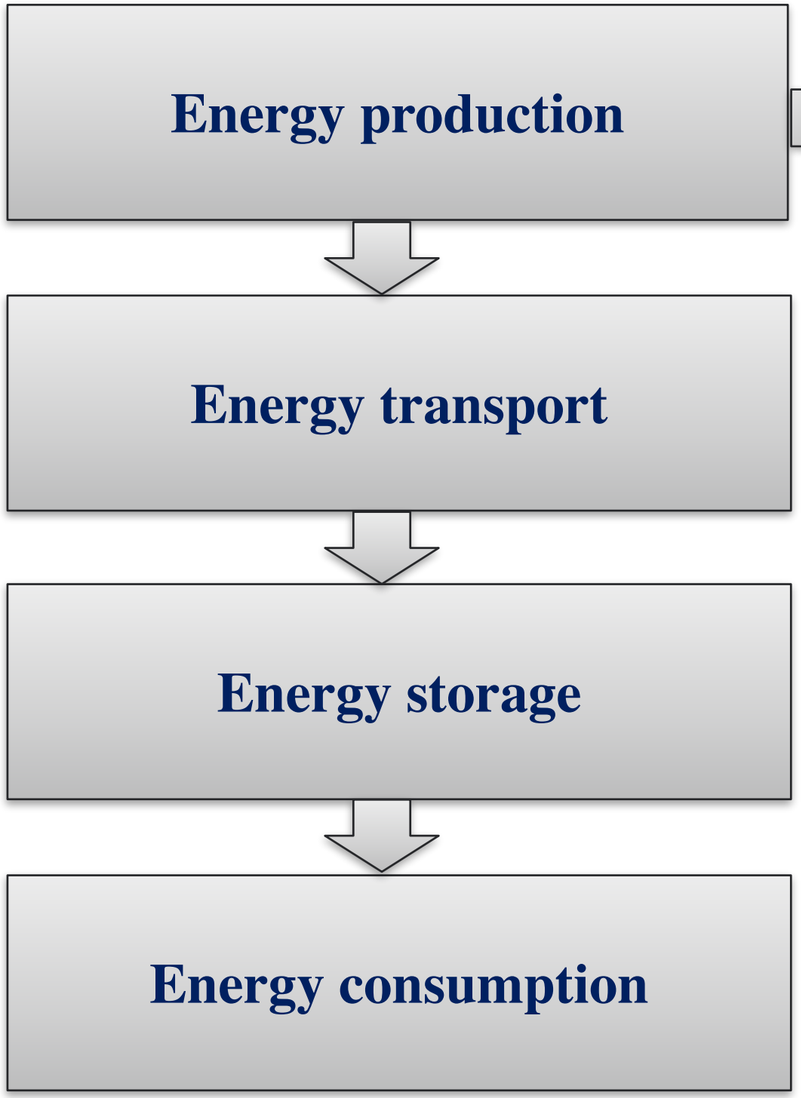
A renewable energy system

YouTube
Lecture 16



A renewable energy system

YouTube
Lecture 16



Best sites
and local

DESERTEC

Eurosolar

<u>International trade and import of energy is more sustainable:</u>
same installation gives 2-3 times more energy

DESERTEC Concept:

Produce renewables where the production is most cost effective

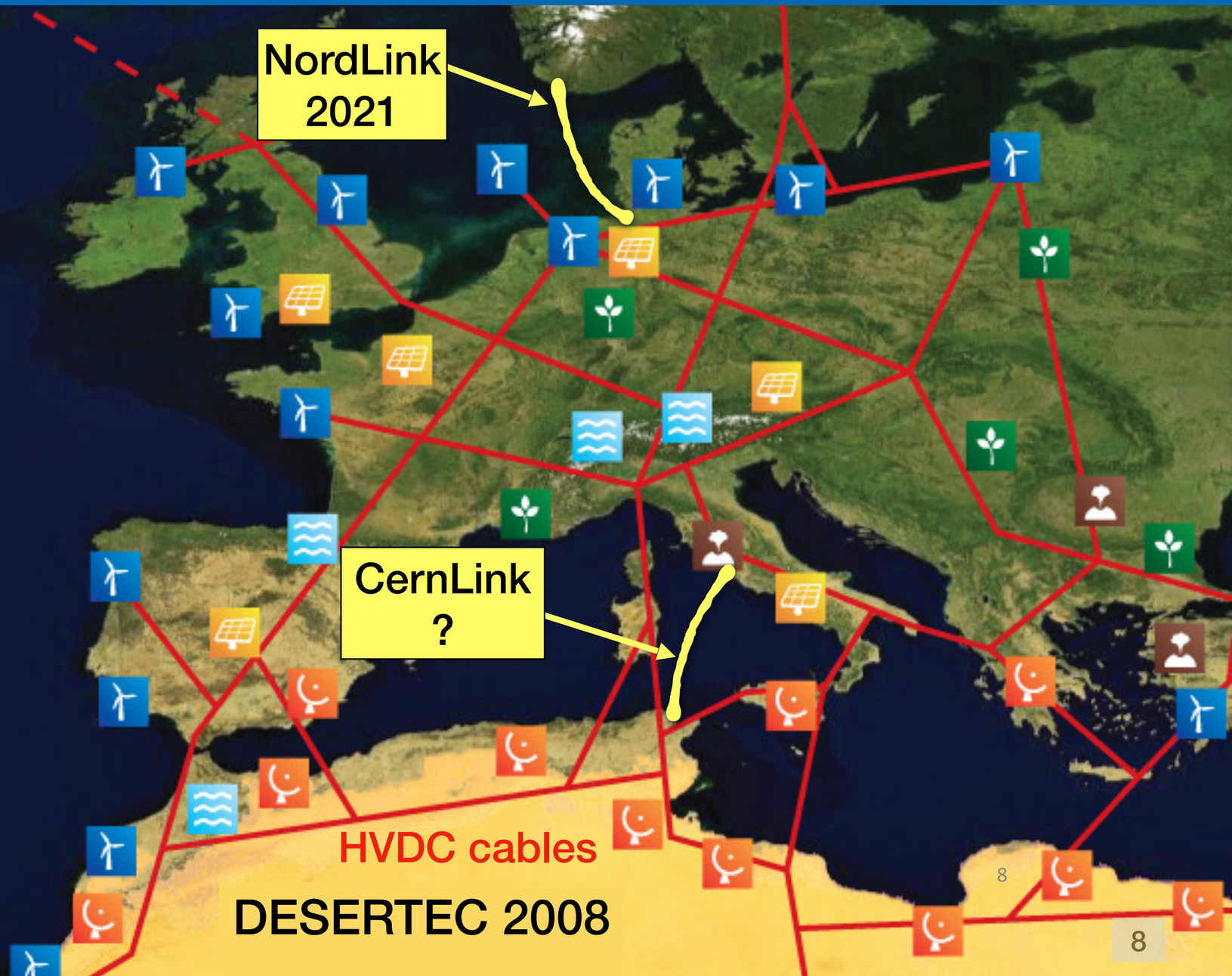
Future of Energy:

Sustainable = Renewable

Fossil energy today: ~ 80%
Paris Agreement: ~ 0% fossil
Solar/wind fraction today: ~ 2%

Ramp up of sun and wind power will not work fast enough

Energy will be scarce!



8

DESERTEC Concept:

Produce renewables where the production is most cost effective

Future of Energy:

Sustainable = Renewable

Fossil energy today: ~ 80%
Paris Agreement: ~ 0% fossil
Solar/wind fraction today: ~ 2%

Ramp up of sun and wind power will not work fast enough

Energy will be scarce!

Deutschland heute: 330 GW fossil

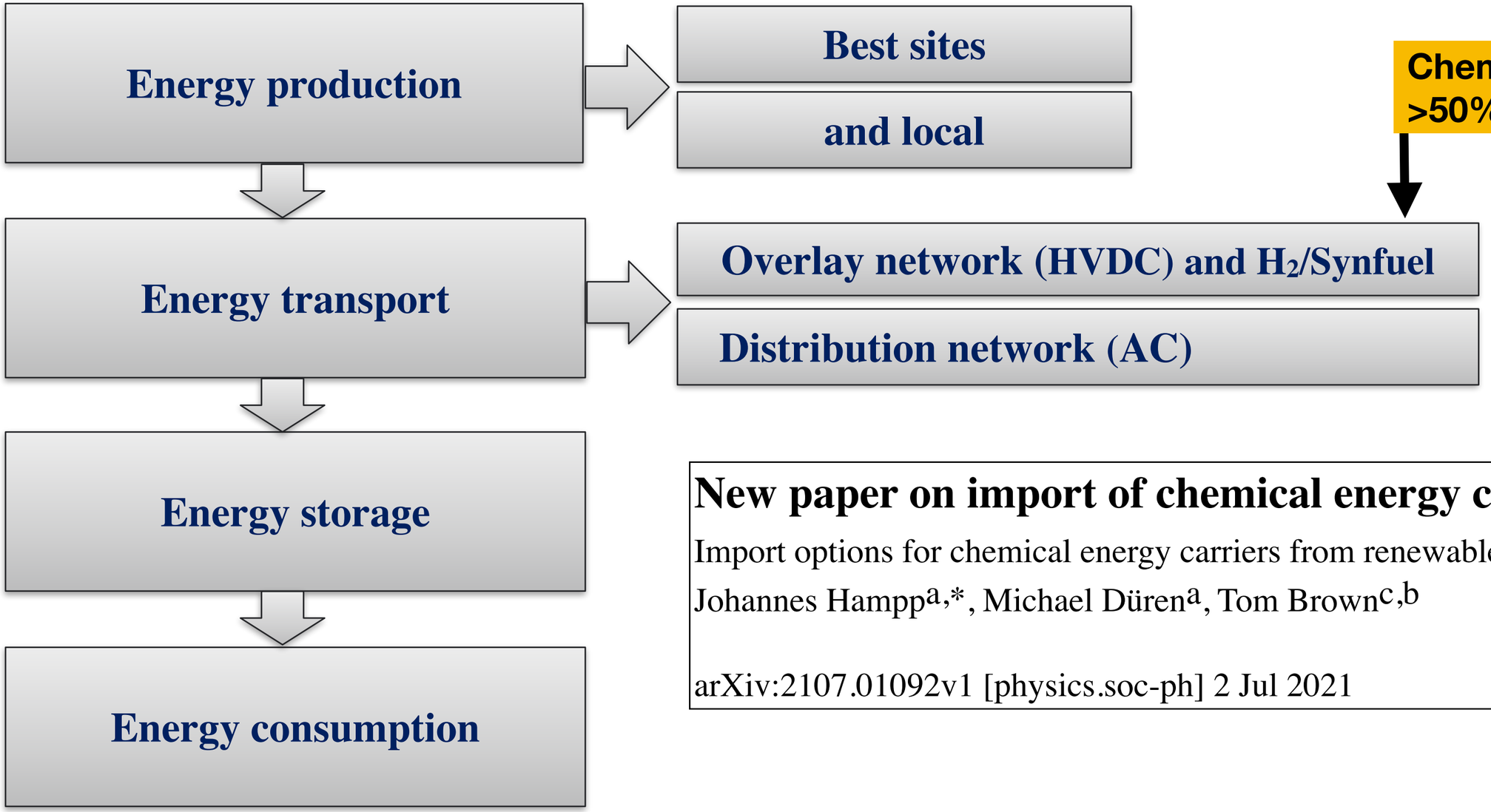
NordLink 2021

DESERTEC 2008

9

A renewable energy system

YouTube
Lecture 16



Chemical energy carriers: >50% is lost by conversion

New paper on import of chemical energy carriers:

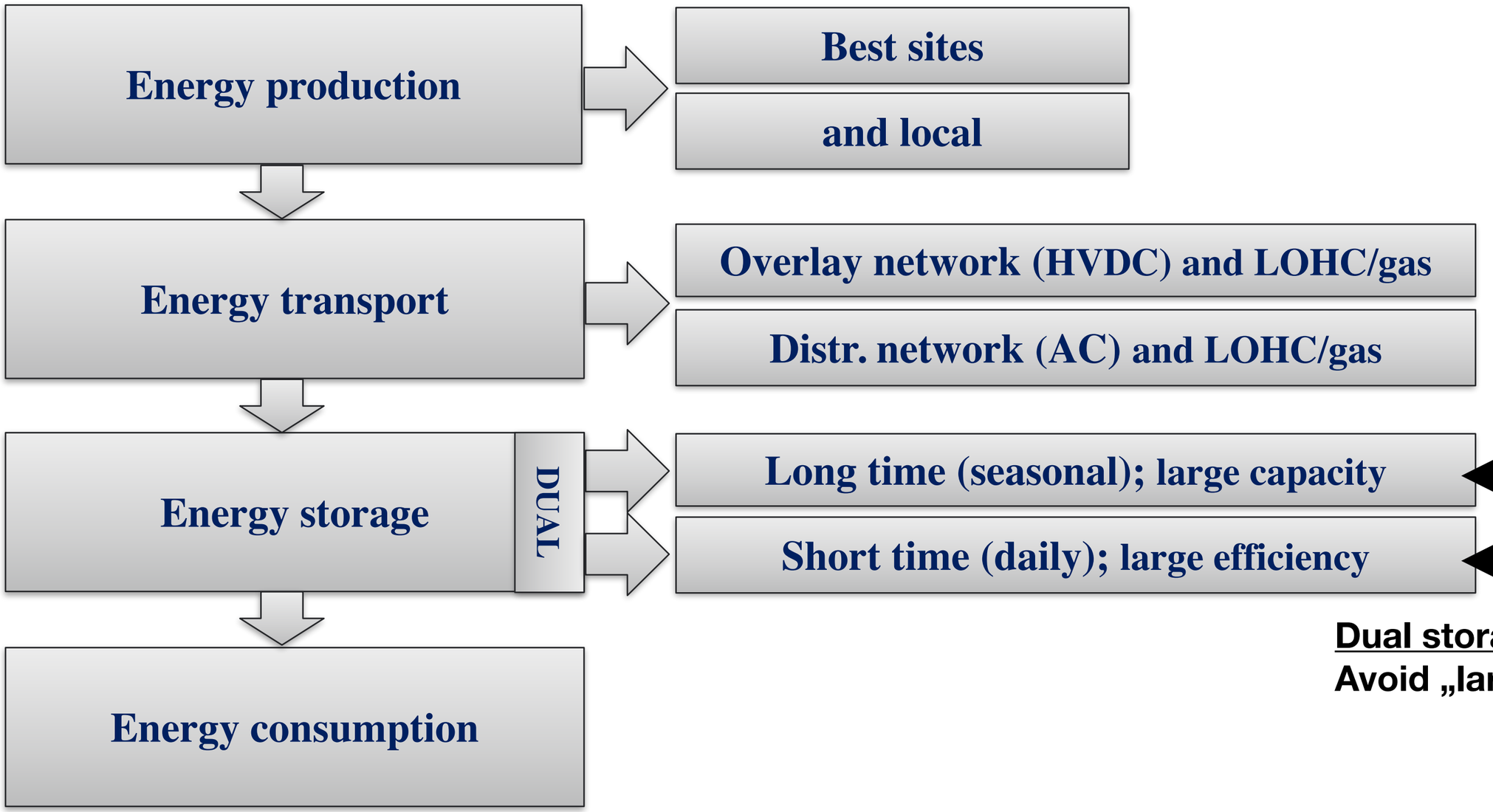
Import options for chemical energy carriers from renewable sources to Germany

Johannes Hampp[a,*], Michael Düren[a], Tom Brown[c,b]

arXiv:2107.01092v1 [physics.soc-ph] 2 Jul 2021

A renewable energy system

YouTube
Lecture 16



Dual storage model:
Avoid „large" and „expensive!“

A renewable energy system

YouTube
Lecture 16

Energy production → Best sites; and local

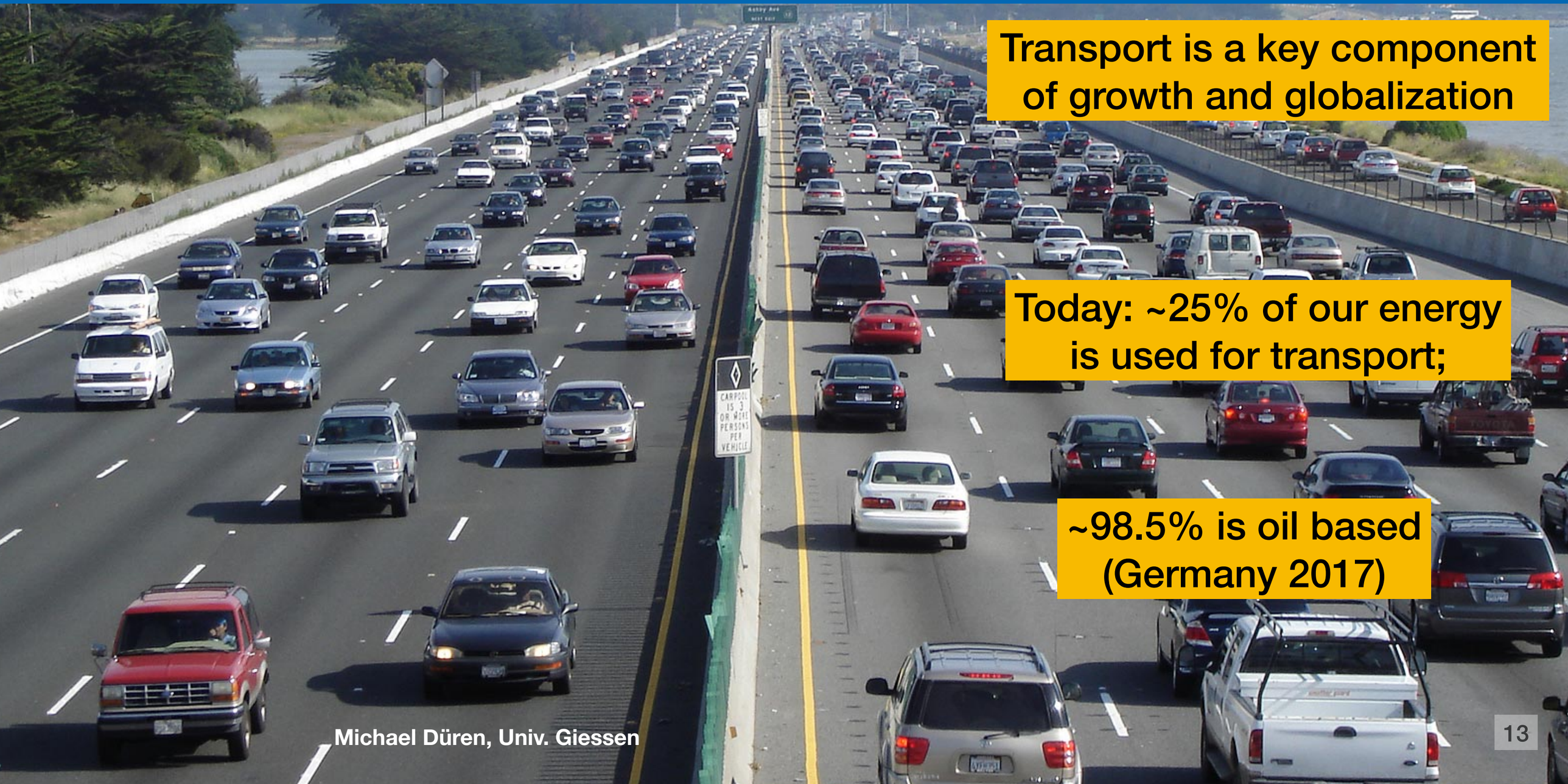
Energy transport → Overlay network (HVDC) and LOHC/gas; Distr. network (AC) and LOHC/gas

Energy storage (DUAL) → Long time (seasonal); large capacity; Short time (daily); large efficiency

Energy consumption → Common Load Manage-ment → Electricity domestic/industry; Mobility; Heat

Speed-Tram with overhead lines and storage!

Energy and Mobility

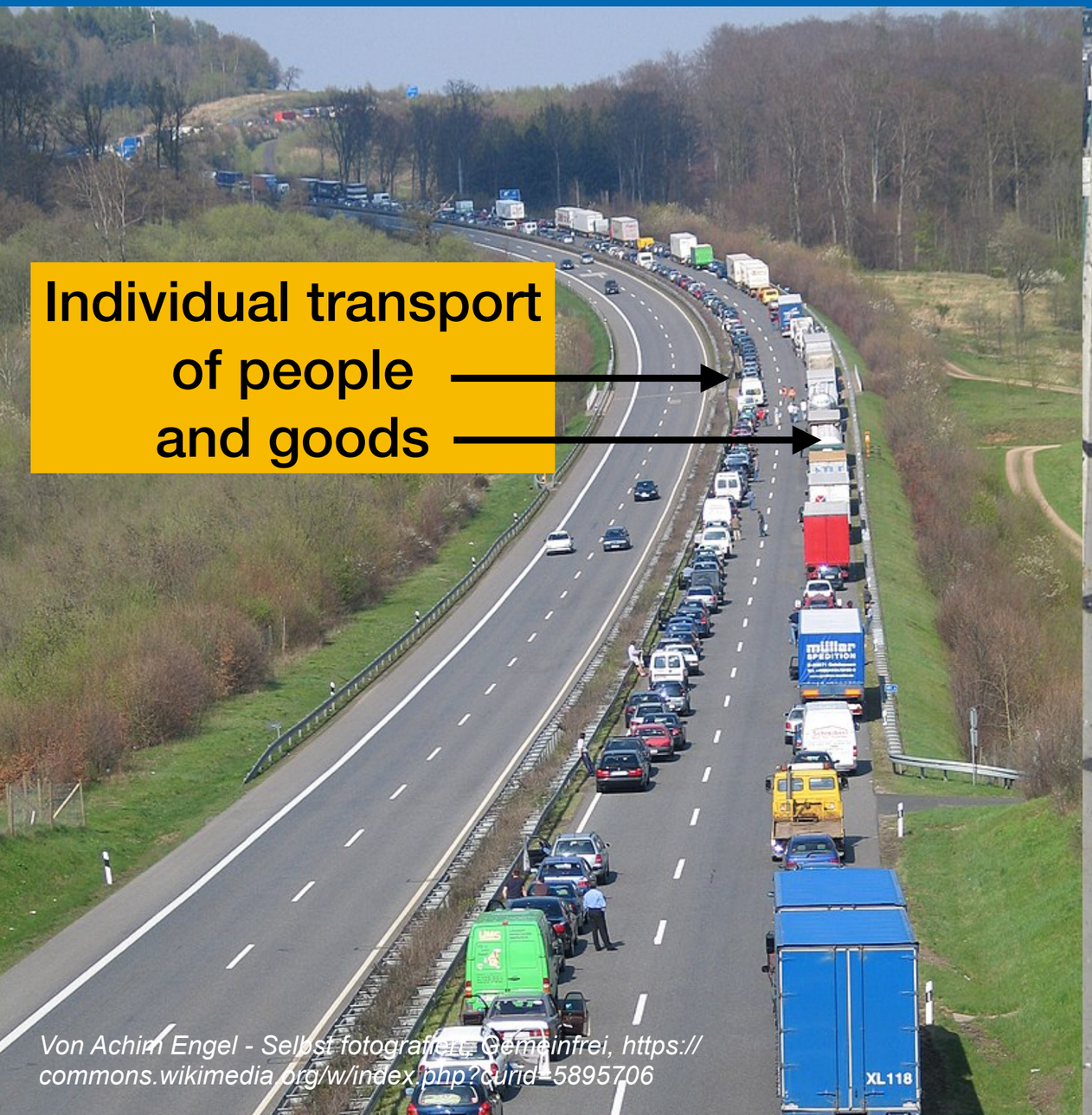


Transport is a key component of growth and globalization

Today: ~25% of our energy is used for transport;

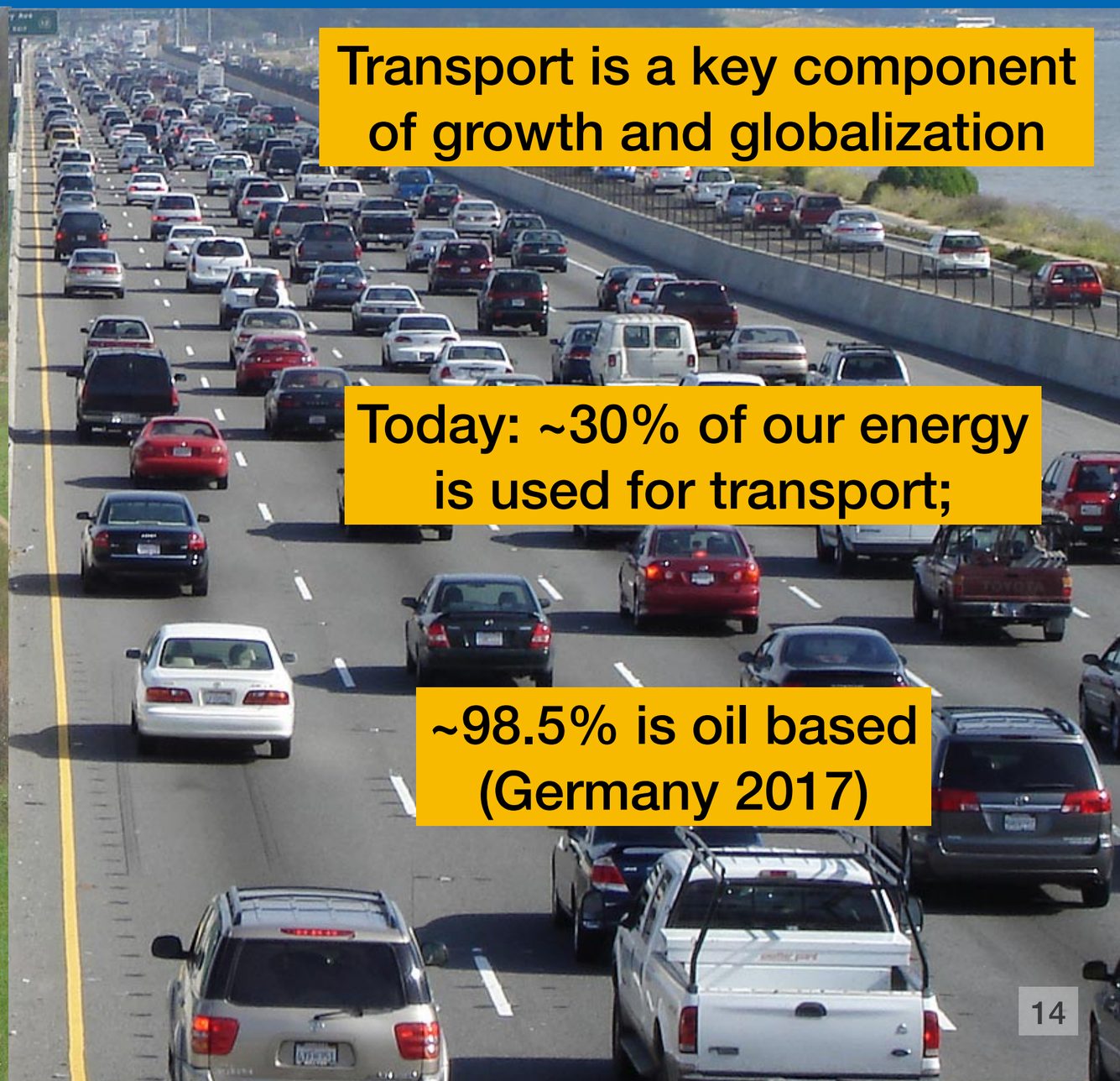
~98.5% is oil based (Germany 2017)

Energy and Mobility



Individual transport of people and goods

Von Achim Engel - Selbst fotografiert, Gemeinfrei, https://commons.wikimedia.org/w/index.php?curid=5895706

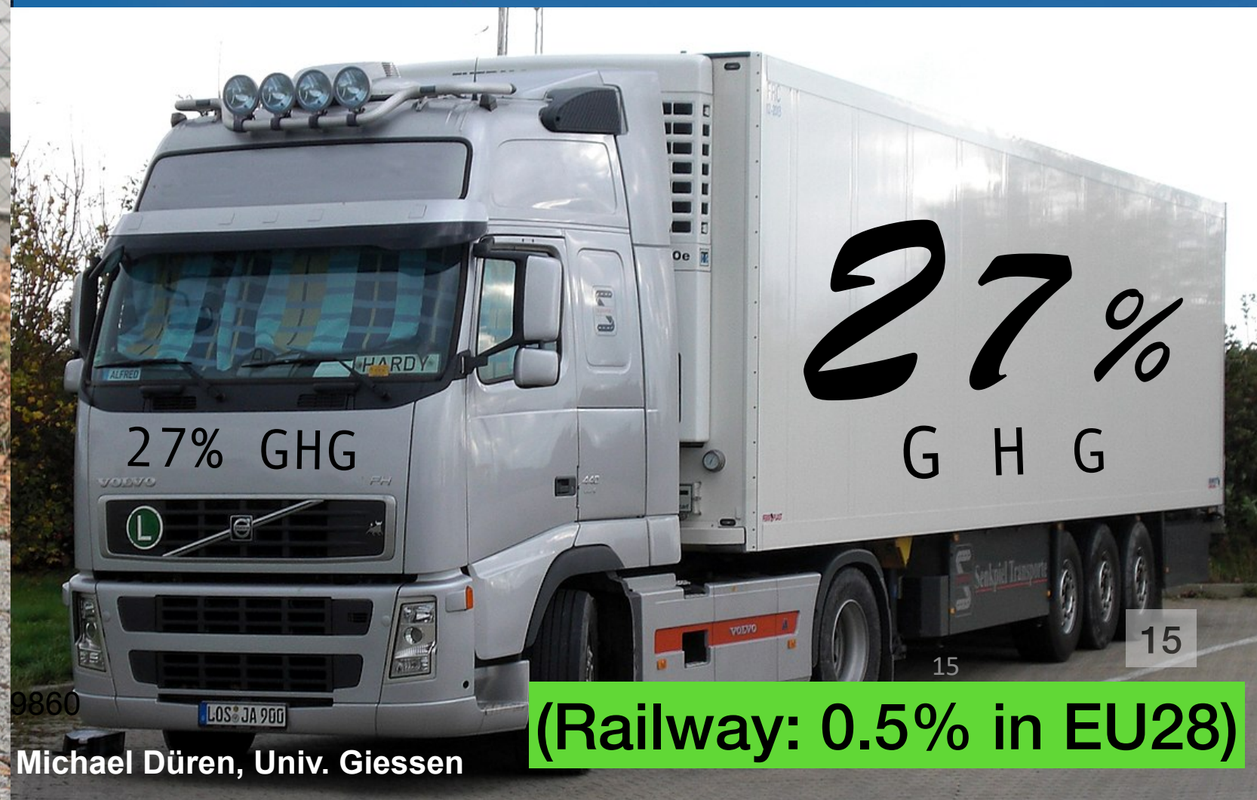


Transport is a key component of growth and globalization

Today: ~30% of our energy is used for transport;

~98.5% is oil based (Germany 2017)

Energy and Mobility



9860

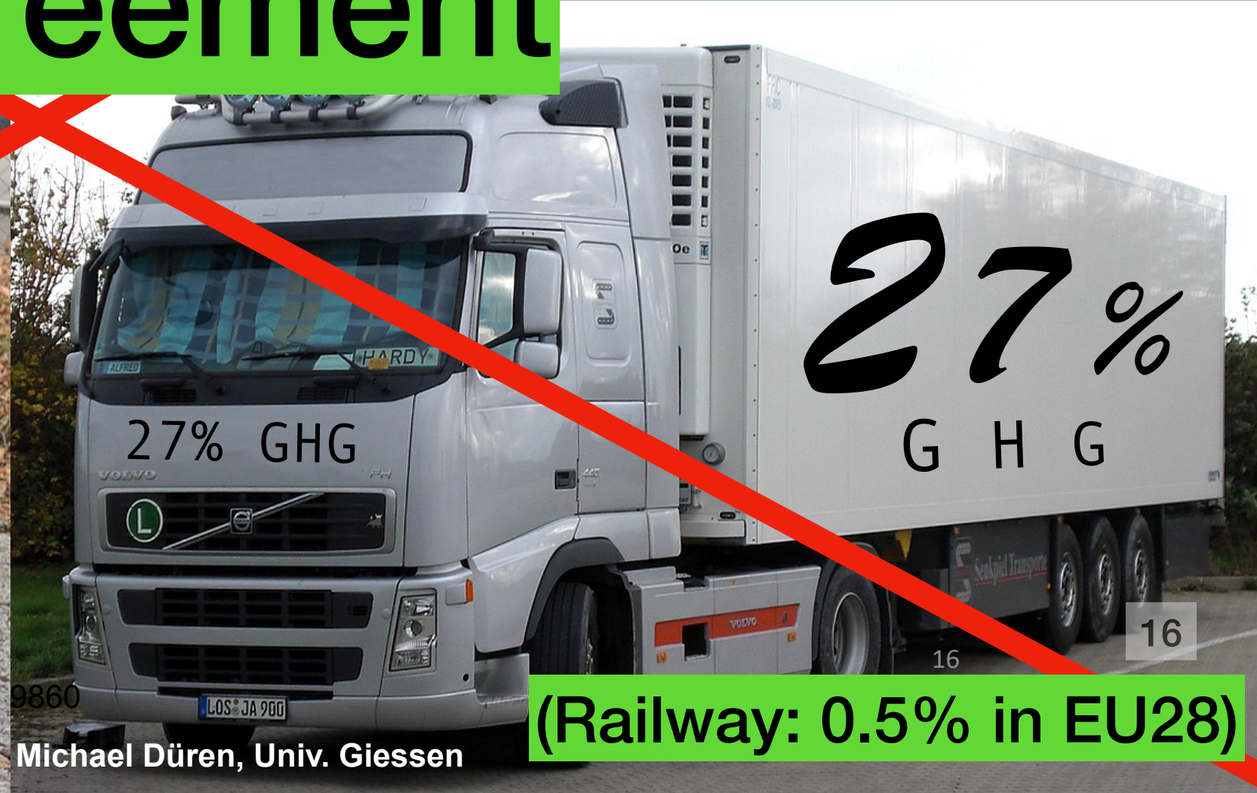
Michael Düren, Univ. Giessen

(Railway: 0.5% in EU28)

15

Energy and Mobility

Paris Agreement



9860

Michael Düren, Univ. Giessen

(Railway: 0.5% in EU28)

The Future of Mobility

Problem specification:

- Fossil fuels have to be stopped
- Energy will be scarce
- Primary energy source will be electricity (wind, solar, hydro, …)
- Renewable fuels only as secondary products: efficiency loss by factor >2 (except bio-fuels)

Energy and Mobility

Historically everything was renewable…

Von Nordevent GmbH - Nordevent GmbH, CC BY-Von
CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=457484
SA 2.0, https://commons.wikimedia.org/w/index.php?curid=755944

Gemeinfrei, https://commons.wikimedia.org/w/index.php?curid=34624

Von Kadereit - Eigenes Werk, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=49574020

The Future of Mobility: 5 Steps

Step 1: Reduce transport of goods

Step 2: Reduce transport of people

Step 3: Short distances by walking + light vehicles

Step 4: Subways in big cities

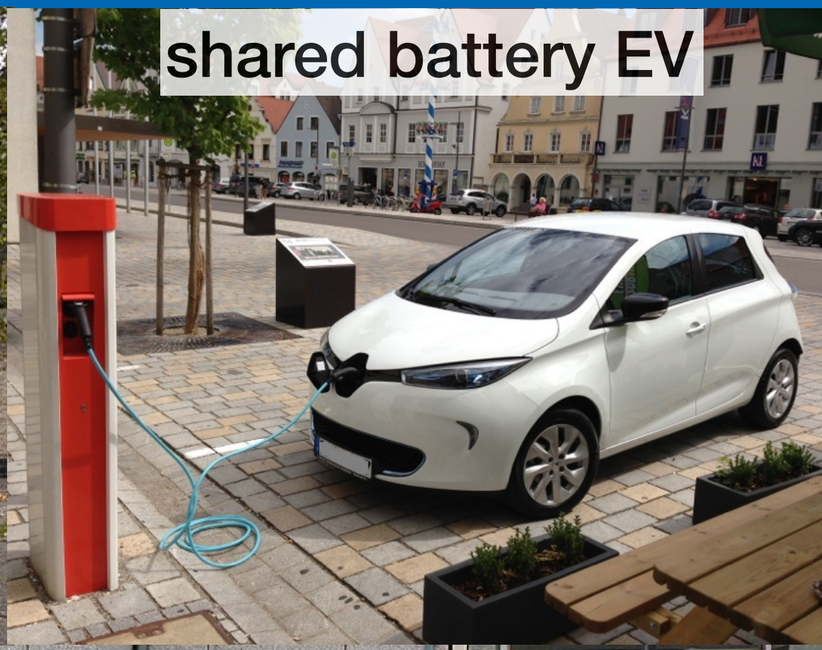
Step 5: Speed Tram on the Auto-Bahn

Michael Düren, Univ. Giessen

Step 3: short distances by walking + light vehicles

e-bike

e-scooter



shared battery EV

e-wheelchair

Von Superbass - Eigenes Werk, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=57936713

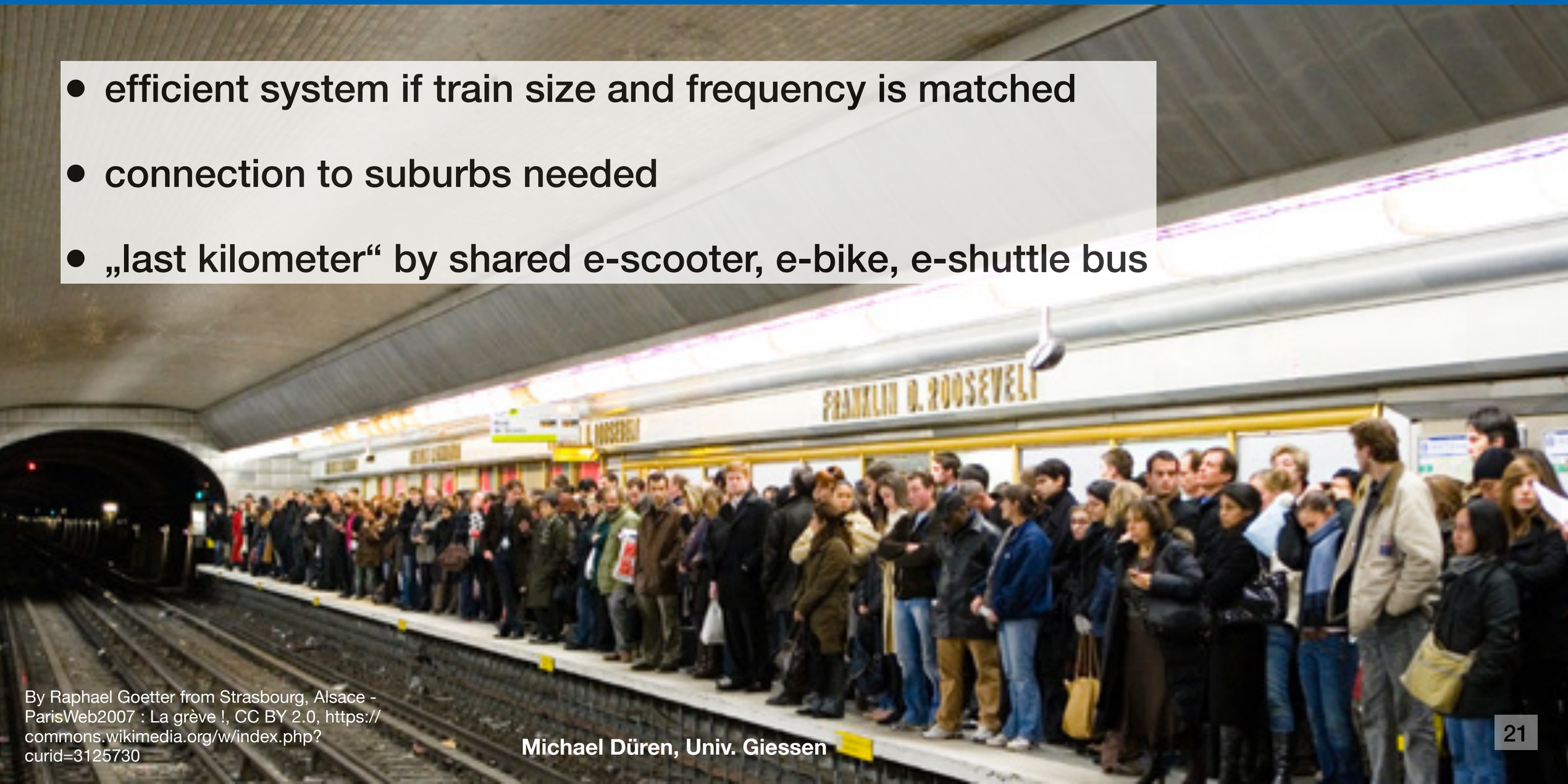
transport e-bike

Von -- Nightflyer (talk) 18:38, 24 June 2013 (UTC) - Selbst fotografiert, CC BY 3.0, https://commons.wikimedia.org/w/index.php?curid=26856813

battery e-transporter

Step 4: Subways in big cities

- efficient system if train size and frequency is matched
- connection to suburbs needed
- „last kilometer“ by shared e-scooter, e-bike, e-shuttle bus



Step 5: ? The main problem: no efficient system for the rest…

- Mobility in rural areas / small towns / suburbs
- Mobility for long distance travel (vacations)
- Transport of goods for medium/long distance

Result:
People want their own car

Michael Düren, Univ. Giessen

Step 5: Speed-Tram on all major roads

Result:
People do not need an own car

Result:
People want their own car

Individual mobility is not the first choice for long distance

Dream of automotive industry:

- SUVs and trucks with hydrogen or synthetic fuels

Show Stopper:

- primary energy consumption too large

  (fuel production + efficiency + friction)

- we can do better by a factor of 10!

5 Minutes of physics…

Does transport really need energy?

No, but…

there is friction on earth

Von NASA - http://spaceflight.nasa.gov/gallery/images/station/crew-36/html/iss036e029800.html, Gemeinfrei, https://commons.wikimedia.org/w/index.php?curid=27640173

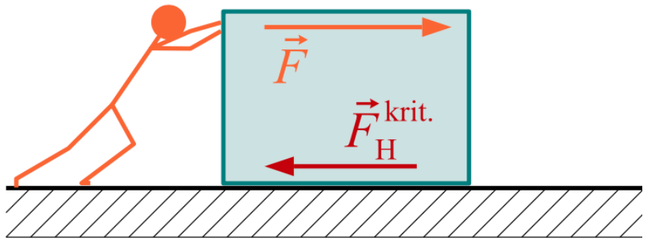
Von NASA Blueshift - set1, CC BY 2.0, https://commons.wikimedia.org/w/index.php?curid=33151485

5 Minutes of physics…

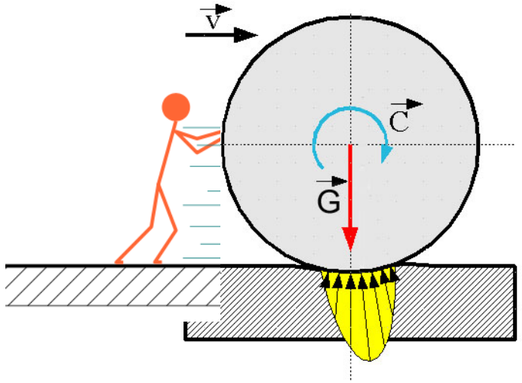
Does transport really need energy?

No, but…

there is friction on earth



Von Debenben - Diese Datei wurde von diesem Werk abgeleitet: Stiction.svg, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=77380421



wheels help!

Von see above - (German Wikipedia, Author: Studi111) bad copy from French Wikibooks Image:Roulement.png Jean-Jacques MILAN 19:06, 30 January 2008 (UTC), CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=3476342

Von NASA Blueshift - set1, CC BY 2.0, https://commons.wikimedia.org/w/index.php?curid=3315

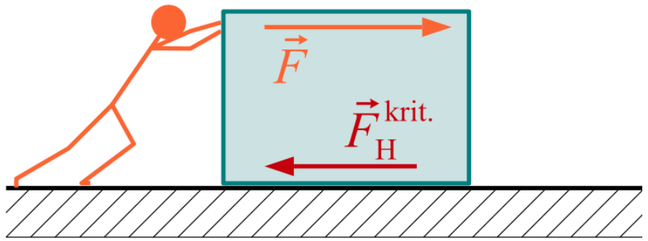
Michael Düren, Univ. Giessen

5 Minutes of physics…

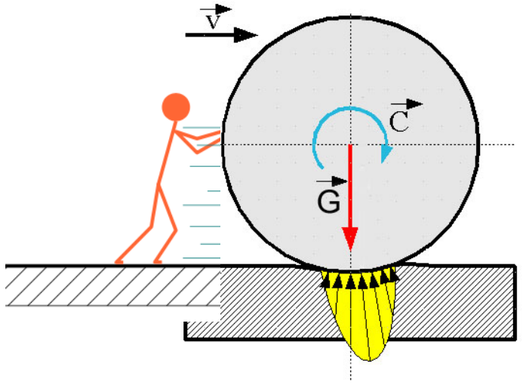
Does transport really need energy?

No, but…

there is friction on earth



Von Debenben - Diese Datei wurde von diesem Werk abgeleitet: Stiction.svg, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=77380421



wheels help!

Von see above - (German Wikipedia, Author: Studi111) bad copy from French Wikibooks Image:Roulement.png Jean-Jacques MILAN 19:06, 30 January 2008 (UTC), CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=3476342

Von NASA Blueshift - set1, CC BY 2.0, https://commons.wikimedia.org/w/index.php?curid=3315

Michael Düren, Univ. Giessen

Hard rails have minimum deformation

5 Minutes of physics…

Energy W for transport over distance s:

rolling resistance $W \sim C_{rr} m s$ **: mass and ground**

$C_{rr} \sim 0.002$ (rail) ; 0.010 (car)

air drag $W \sim v^2 A s$**: speed and cross section**

ascending slope $W \sim mh$**: mass and height**
(can be recuperated)

acceleration $W \sim mv^2$**: speed and mass**
(can be recuperated)

efficiency of engine: type

$\eta \sim 95\,\%$ (electric) ; $60\,\%$ (fuel cell) ; $40\,\%$ (combustion)

efficiency of recuperation: none / battery / grid

5 Minutes of physics…

Energy *W* for transport over distance *s*:

rolling resistance $W \sim C_{rr} m s$ **: mass and ground**

$C_{rr} \sim 0.002$ (rail) ; 0.010 (car)

air drag $W \sim v^2 A s$**: speed and cross section**

ascending slope $W \sim mh$**: mass and height**
(can be recuperated)

acceleration $W \sim mv^2$**: speed and mass**
(can be recuperated)

efficiency of engine: type

$\eta \sim 95\,\%$ (electric) ; $60\,\%$ (fuel cell) ; $40\,\%$ (combustion)

efficiency of recuperation: none / battery / grid

Energy losses in a typical car

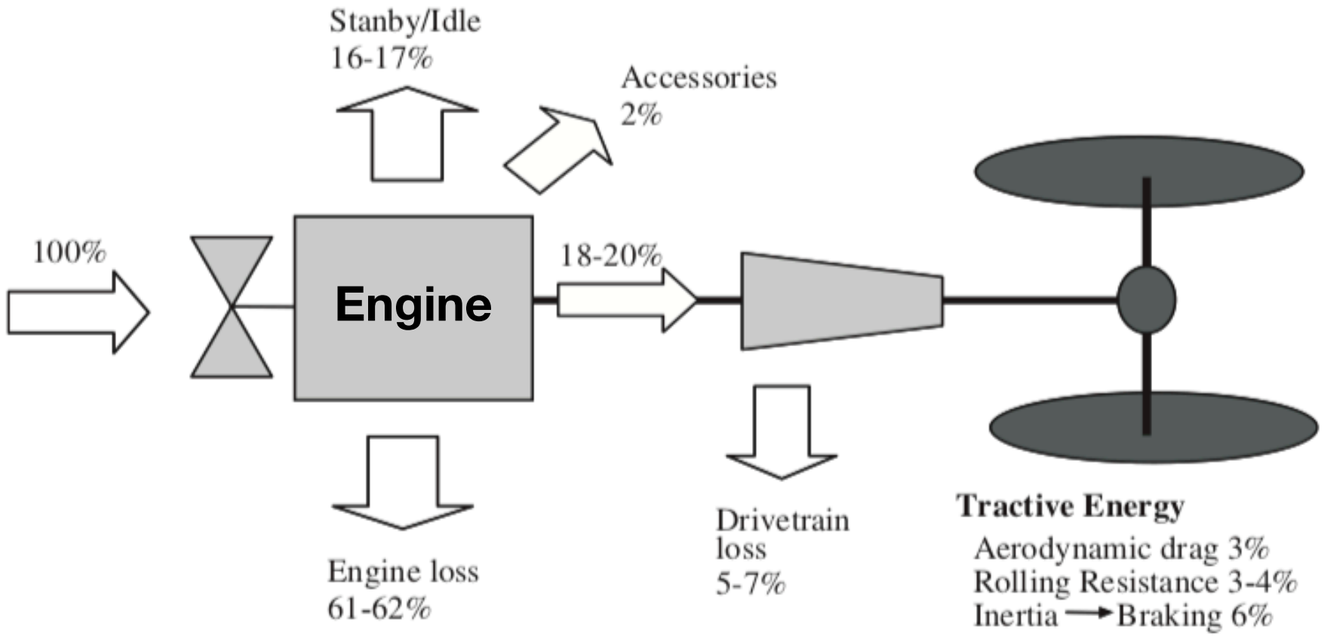


Figure 9.31 | Energy use in a typical gasoline passenger vehicle (mid-size, urban driving mode). Source: based on Kobayashi et al., 2009.

Von NASA Blueshift - set1, CC BY 2.0, https://commons.wikimedia.org/w/index.php?curid=33151485

https://iiasa.ac.at/web/home/research/Flagship-Projects/Global-Energy-Assessment/GEA_Chapter9_transport_hires.pdf

5 Minutes of physics...

YouTube
Lecture 28

Energy W for transport over distance s:

rolling resistance $W \sim C_{rr} m s$ **: mass and ground**

$C_{rr} \sim 0.002$ (rail) ; 0.010 (car)

air drag $W \sim v^2 A s$**: speed and cross section**

ascending slope $W \sim mh$**: mass and height**
(can be recuperated)

acceleration $W \sim mv^2$**: speed and mass**
(can be recuperated)

efficiency of engine: type

$\eta \sim 95\,\%$ (electric) ; $60\,\%$ (fuel cell) ; $40\,\%$ (combustion)

efficiency of recuperation: none / battery / grid

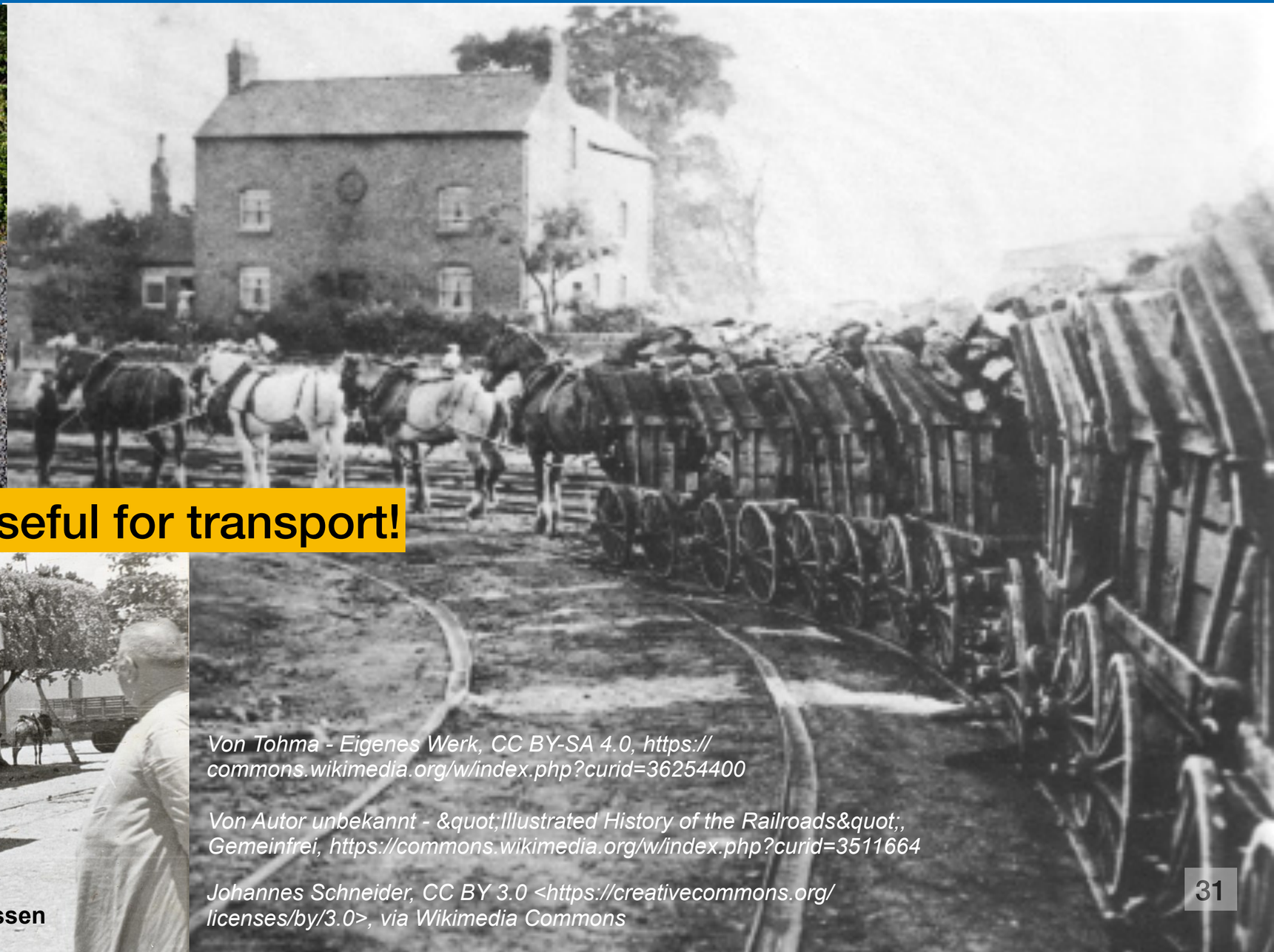
Energy efficient transport:

- **trains on rails**
- **not too heavy**
- **not too fast**
- **limited cross section (or large length)**
- **electric engines**
- **overhead lines, with recuperation to the grid**
- **high occupancy (many people, many goods)**

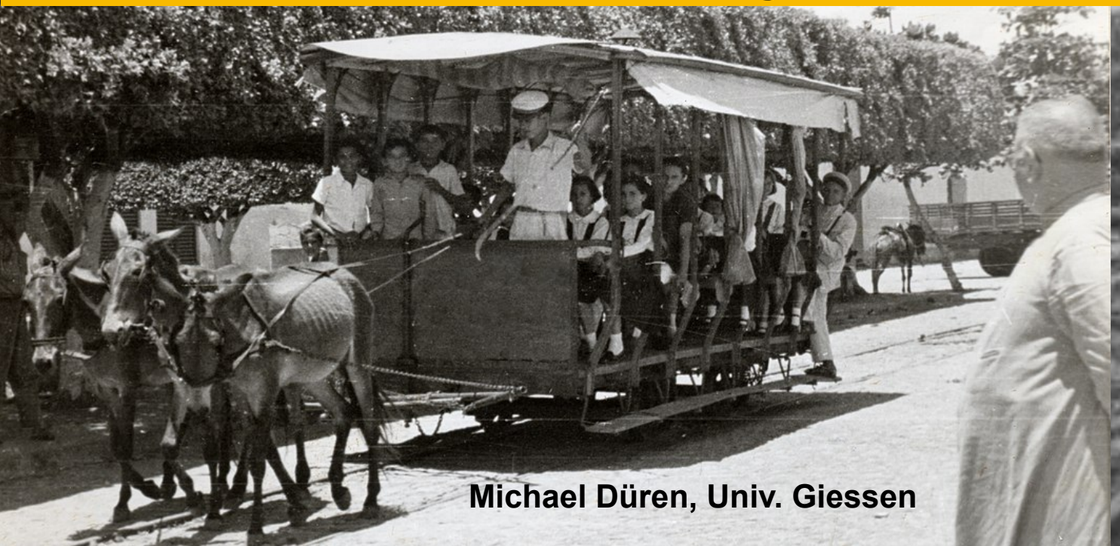
  (not sending around empty trains all day)

Factor of 10 saved easily!

Energy and Mobility



Rails turned out to be very useful for transport!



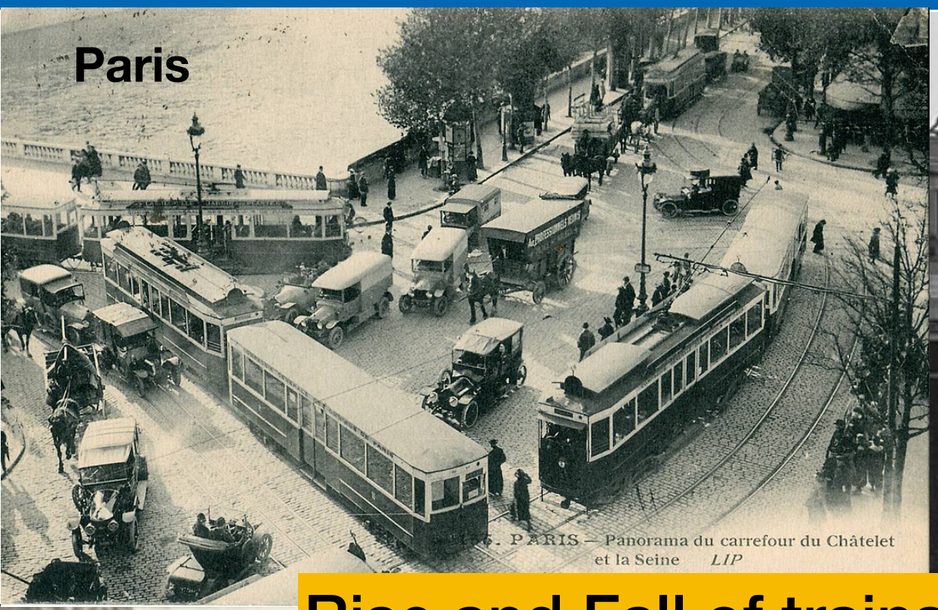
Michael Düren, Univ. Giessen

Von Tohma - Eigenes Werk, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=36254400

Von Autor unbekannt - "Illustrated History of the Railroads", Gemeinfrei, https://commons.wikimedia.org/w/index.php?curid=3511664

Johannes Schneider, CC BY 3.0 <https://creativecommons.org/licenses/by/3.0>, via Wikimedia Commons

Energy and Mobility



Rise and Fall of trains and trams

By Scanné par Claude Shoshany - Collection personnelle, Public Domain, https://commons.wikimedia.org/w/index.php?curid=5653684

Michael Düren, Univ. Giessen

Los Angeles Times, Public domain, via Wikimedia Commons https://commons.wikimedia.org/w/index.php?curid=56225649

Speed-Tram for passengers

YouTube
Lecture 29

Speed-Tram for cargo

YouTube
Lecture 29

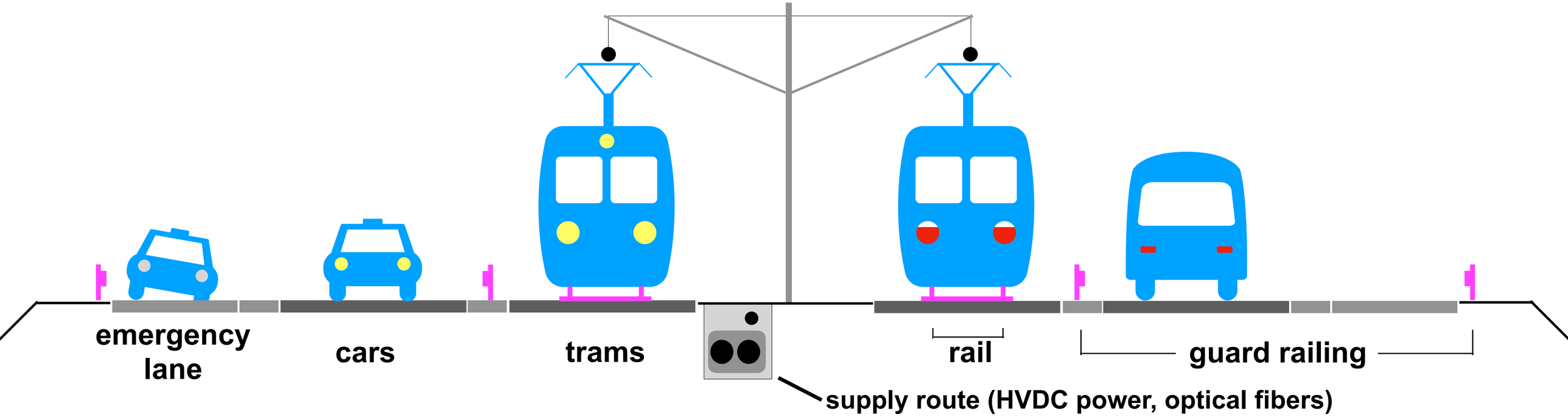
By Source, Fair use, https://en.wikipedia.org/w/index.php?curid=51646726

Von Marco Präg, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=515252

Speed-Tram on the Auto-Bahn

YouTube
Lecture 29

The new Auto-Bahn



By Source, Fair use, https://en.wikipedia.org/w/index.php?curid=51646726

Speed-Tram

Factor 10 saved!

Energy Efficiency:

- rails, electric, recuperation, overhead lines where possible, otherwise batteries

By Source, Fair use, https://en.wikipedia.org/w/index.php?curid=51646726

Von MDRX - Eigenes Werk, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=76673765

Speed-Tram

Energy Efficiency:

- rails, electric, recuperation, overhead lines where possible, otherwise batteries

Factor 10 saved!

Stabilization of national grid:

- tram batteries used as short-term storage

blackout problem solved!

By Source, Fair use, https://en.wikipedia.org/w/index.php?curid=51646726

Von MDRX - Eigenes Werk, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=76673765

Speed-Tram

Energy Efficiency:

- rails, electric, recuperation, overhead lines where possible, otherwise batteries

Factor 10 saved!

Stabilization of national grid:

- tram batteries used as short-term storage

blackout problem solved!

Landuse (biodiversity):

- use existing roads and highways

reuse automobile infrastructure for railways and power lines

By Source, Fair use, https://en.wikipedia.org/w/index.php?curid=51646726

Von MDRX - Eigenes Werk, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=76673765

Imagine a future world with Speed-Trams…

Infrastructure:

Rails on all major roads

Overhead lines (most of the way)

**Speed-Tram has batteries
for historic town centers, crossings,
low-ceilinged tunnels or underbridges**

**No additional landuse for infrastructure;
Use automotive infrastructure (roads, highways)
Auto-Bahn**

Imagine a future world with Speed-Trams…

“Phase transition“ from individual to public transport needed

The secret of speed:

direct connections from all A’s to all B’s possible

- **A typical highway frequency is ~100 000 cars and lorries/day!**
- **Speed-Trams every 1-2 minutes needed (for 100 000 passengers/day/highway)**
- **no long waiting time for next train**
- **combination of**
  - **scheduled and „on demand“ trains**
  - **short and long trains**
  - **cargo and passenger trains**

Von MDRX - Eigenes Werk, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=76673765

Imagine a future world with Speed-Trams…

Comfort choice:

- direct train „on demand“ from home to home (nearest tram stop)

Budget choice:

- scheduled train with change at several stations

Extras:

sleeper cabin, quiet office table, meeting room, small cabin for extensive (video) phone calls, indoor playground for children, gym, massage, pub-atmosphere: “drink and ride“, after-work parties,…

dining room, breakfast, food orders, …

Von Hinnerk R (Hinnerk Rümenapf) - Eigenes Werk, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=29339404

Speed-Tram

Speed:

- 130 km/h on highway, frequency: 1-2 min, no intermediate stops on long distance

much shorter travel time compared to today's trains

https://www.zugreisen.ch/de/zug/europa/belmond-grand-hibernian

Speed-Tram

Speed:

- 130 km/h on highway, frequency: 1-2 min, no intermediate stops on long distance

much shorter travel time compared to today's trains

Comfort:

- on-demand, home-to-home for extra price (+/- 1 km), special comfort cars (dinner, sleeping cars,…)

https://www.zugreisen.ch/de/zug/europa/belmond-grand-hibernian

Speed-Tram

Speed:

- 130 km/h on highway, frequency: 1-2 min, no intermediate stops on long distance

Comfort:

- on-demand, home-to-home for extra price (+/- 1 km), special comfort cars (dinner, sleeping cars,…)

Safty:

- 170 000 accidents on German highways/year

much shorter travel time compared to today's trains

saves the life of your children!

https://www.zugreisen.ch/de/zug/europa/belmond-grand-hibernian

Speed-Tram

Speed:

- 130 km/h on highway, frequency: 1-2 min, no intermediate stops on long distance

Comfort:

- on-demand, home-to-home for extra price (+/- 1 km), special comfort cars (dinner, sleeping cars,…)

Safty:

- 170 000 accidents on German highways/year

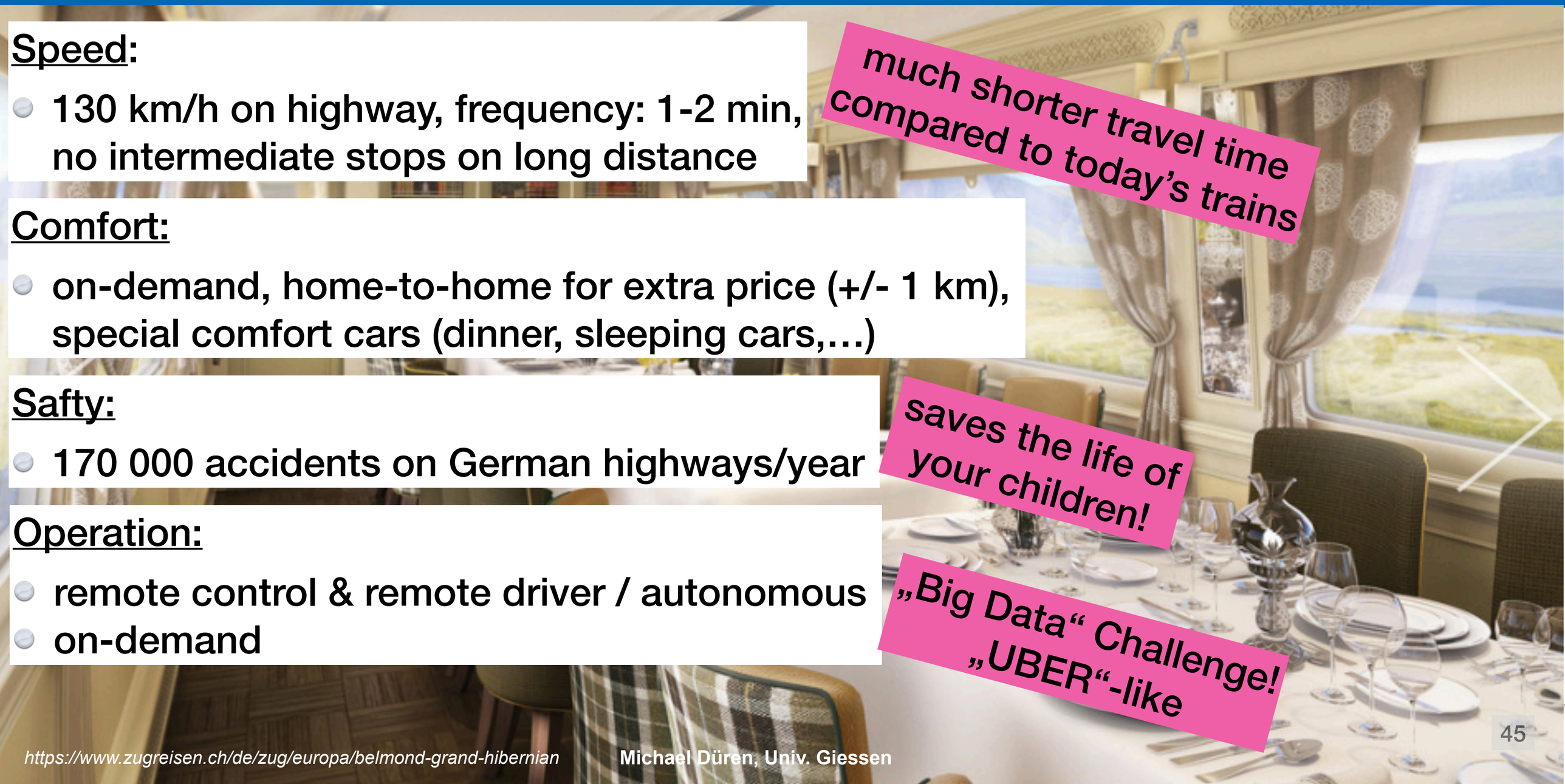
Operation:

- remote control & remote driver / autonomous
- on-demand

much shorter travel time compared to today's trains

saves the life of your children!

„Big Data" Challenge! „UBER"-like



https://www.zugreisen.ch/de/zug/europa/belmond-grand-hibernian

4 Steps to a future world with Speed-Trams…

1. Bus:
(on demand)

2. Trolleybus:

3. Autonomous Rail Rapid Transit

4. Speed-Tram on rails

4 Steps to a future world with Speed-Trams…

1. Bus:
(on demand)

2. Trolleybus:

3. Autonomous Rail Rapid Transit:

4. Speed-Tram on rails:

Funktioniert erst dann effektiv, wenn sehr viele Leute das System nutzen

Hessen

MITTWOCH, 6. OKTOBER 2021 | 77. JAHRGANG | NR.232 Frankfurter Rundschau

Frankfurt startet Rufbusservice „Knut“

E-Fahrzeuge sind künftig auf Abruf in den nördlichen Stadtteilen unterwegs

VON FLORIAN LECLERC

Der Start des Rufbusservices „Knut“ im Frankfurter Norden ist gebührend gefeiert worden. Auf dem Markplatz im Stadtteil Bonames gab es Cappuccino und Brötchen mit Wurst. Zwei Rufbusse wurden von den Passantinnen und Passanten betrachtet. Oberbürgermeister Peter Feldmann (SPD) lobte das Projekt, bei dem

Wer den Service bucht, kann an etwa 600 virtuellen Haltestellen in den vier Stadtteilen Bonames, Harheim, Nieder-Erlenbach und Nieder-Eschbach ein- und aussteigen – also praktisch vor der Haustür. „Wir werden

denen wohl Knut Ringat beteiligt war, stieg Frankfurt doch mit ein. Wie hätte es auch ausgesehen, wenn die Pendlerhauptstadt im Rhein-Main-Gebiet bei einem On-Demand-Projekt im Rhein-Main-Gebiet nicht mitgemacht hätte?

Der Bund gab 27 Millionen Euro Fördermittel für das Projekt, die sich zehn Städte und Landkreise teilten. „Das Geld ist nun aber weg“, sagte Verkehrsdezernent Stefan Majer (Grüne). Die Stadt gebe bis Ende 2024 rund 600 000 Euro für die drei „Knut“-Busse dazu – wenn die Stadt mehr Busse haben wolle, müsse sie sie selbst komplett bezahlen. Hoffnungen, dass das geschehen wird, machte er nicht.

Weitere Hoffnungen an die drei E-Vitos von Mercedes, die von morgens fünf Uhr bis ein Uhr nachts fahren, blieben unerfüllt. Nur einer der drei Busse kann Menschen im Rollstuhl befördern, was die Frankfurter Behinderten-Arbeitsgemeinschaft beklagt. Die Rufbusse bleiben innerhalb d... Stadtgrenze und lass...

4 Steps to a future world with Speed-Trams…

1. Bus:
(on demand)

2. Trolleybus:
(overhead line)

3. Autonomous Rail Rapid Transit:
(Train with virtual rails)

4. Speed-Tram on rails:
(best energy efficiency;
& grid stabilization)

4 Steps to a future world with Speed-Trams…

1. Bus:
(on demand)

2. Trolleybus:
(overhead line)

3. Autonomous Rail Rapid Transit:
(Train with virtual rails)

4. Speed-Tram on rails:
(best energy efficiency;
& grid stabilization)

Marburg O-Bus

op Marburg / Zurück in die Zukunft: Oberleitung soll der Antrieb der Moderne werden

Zurück in die Zukunft: Oberleitung soll der Antrieb der Moderne werden

Bund unterstützt Planungen mit 1,5 Millionen Euro / Bergauf, bergab werden Batterien geladen

4 Steps to a future world with Speed-Trams…

1. Bus:
(on demand)

2. Trolleybus:
(overhead line)

3. Autonomous Rail Rapid Transit:
(Train with virtual rails)

4. Speed-Tram on rails:
(best energy efficiency;
& grid stabilization)

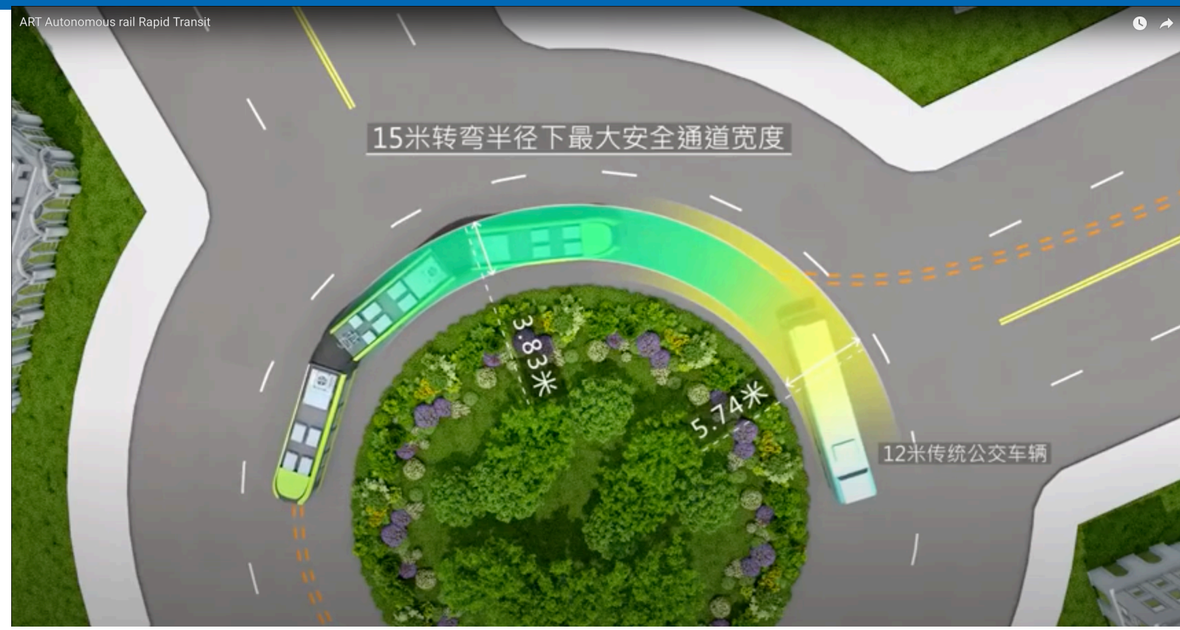
Michael Düren, Univ. Giessen

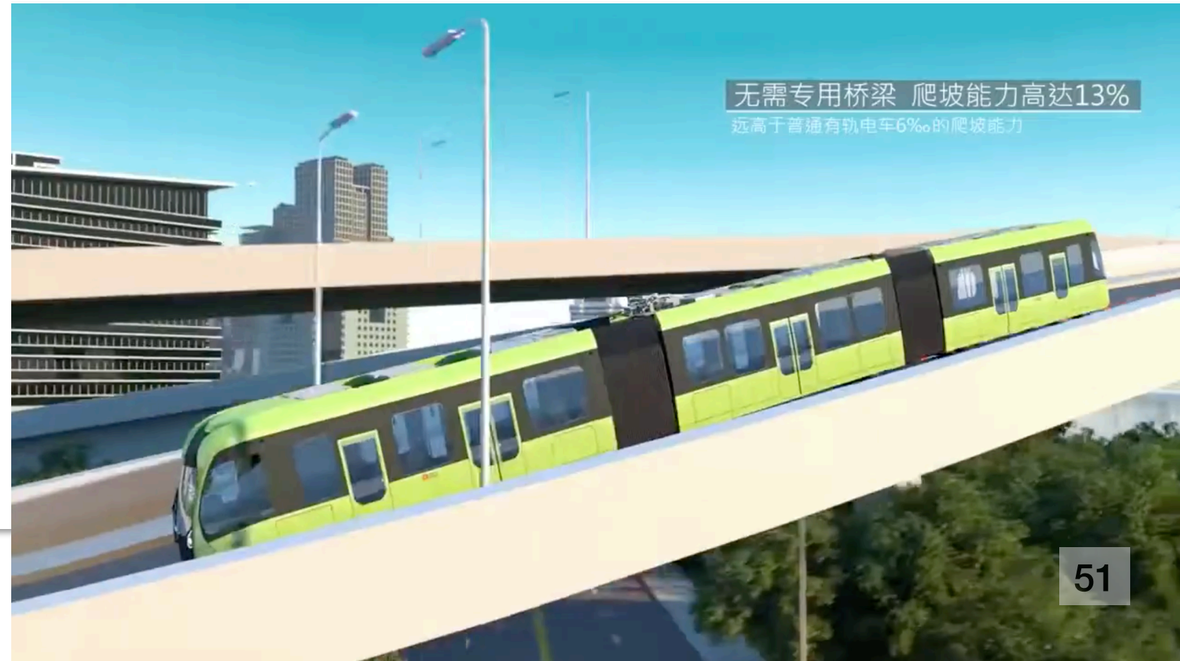
4 Steps to a future world with Speed-Trams…

3. Autonomous Rail Rapid Transit:

Example:

https://www.youtube.com/watch?v=bXB87NWHvDg





Schritt zur Speed-Tram: Oberleitung + Schienen + Cargo + Comfort + on Demand


World's first unmanned smart
electric bus trials in S. China

4 Steps to a future world with Speed-Trams…

1. Bus:
(on demand)

2. Trolleybus:
(overhead line)

3. Autonomous Rail Rapid Transit (ART):
(Train with virtual rails)

4. Speed-Tram on rails:
(best energy efficiency;
& grid stabilization)

Michael Düren, Univ. Giessen

Speed-Tram =
ART + rails + overhead line
+ cargo + operation „on Demand“

Auto-Bahn