PAUL SCHERRER INSTITUT

PSI

Stefan Hirschberg :: Head, Laboratory for Energy Systems Analysis :: Energy Divisions :: PSI

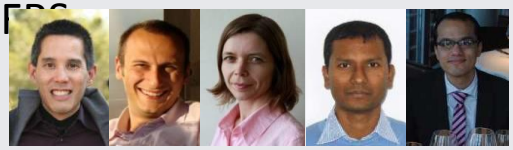
Laboratory for Energy Systems Analysis (LEA)

NES Event, PSI, 18 October 2016

Laboratory for Energy Systems Analysis (LEA)

Laboratory for Energy Systems Analysis (LEA)

S. Hirschberg

Technology Assessment (TA) P. Burgherr	Energy Economics (EE) T. Kober	Risk & Human Reliability (RHR) V. Dang
 FRS Risk Group		  FRS Human Performance & Resilience Group
- **9 staff scientists** - **2 PhDs** - **1 guest scientist** **Future Resilient Systems, SG:** - **1 Postdoc** - **2 PhDs** - **1 Technical Specialist** - **1 Postdoc vacancy**	- **3 staff scientists** - **2 Postdocs** - **2 PhDs** - **1 Honorary Scientist** - **1 staff scientist vacancy**	- **4 staff scientists** - **1 postdoc** - **2 PhDs** - **1 vacancy (1 staff scientist)** **Future Resilient Systems, SG:** - **1 Postdoc** - **3 vacancies (1 Postdoc, 1 PhD, 1 Technical Specialist)**

Project Portfolio: Technology Assessment & Energy Economics

Electricity

- SCCER SoE (CTI)
- Energy Perspectives (SFOE)
- Powerdesign (SFOE)
- Swisshydro (VSE)
- Bi-level El. Markets (SFOE)
- POWER UP (EC)
- ALKAMMONIA (EC)
- Swissnuclear LCA (sn)
- HTR MSR (PSEL)

Energy

- Global Energy Scenarios (WEC)
- IDEAS4Cities (CCEM)
- INSIGHT-E (EC)

Storage

- SCCER Storage(CTI)
- ISCHESS (CCEM, SER)
- AA-CAES (NRP70)
- THRIVE (NRP70)
- ESI Platform

Tools, Databases & Communication

- TIMES, STEM, etc.
- ecoinvent
- ENSAD
- Mighty MCDA
- OCELOT
- Energiespiegel

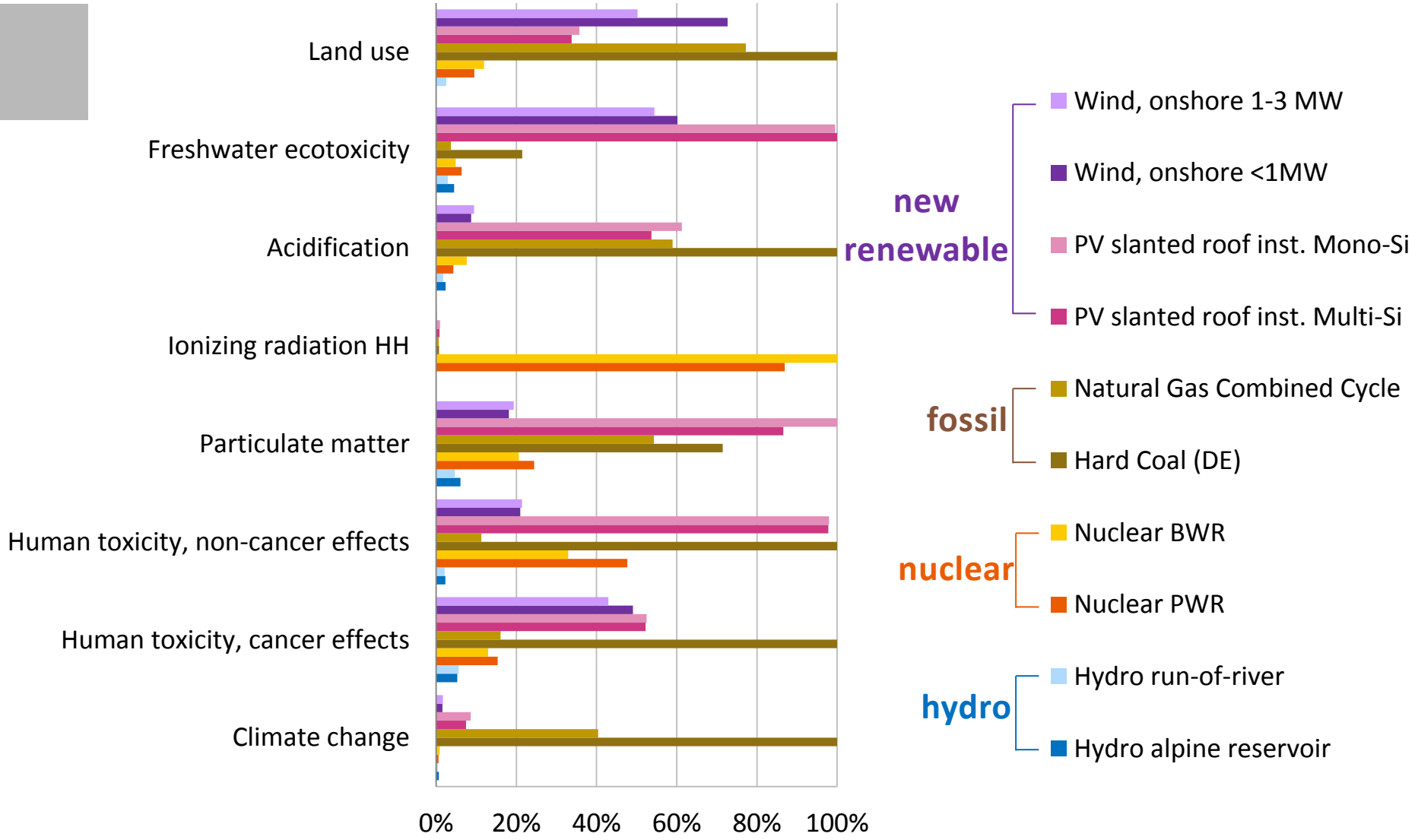
Mobility

- SCCER Mobility(CTI)
- THELMA (CCEM, SER)

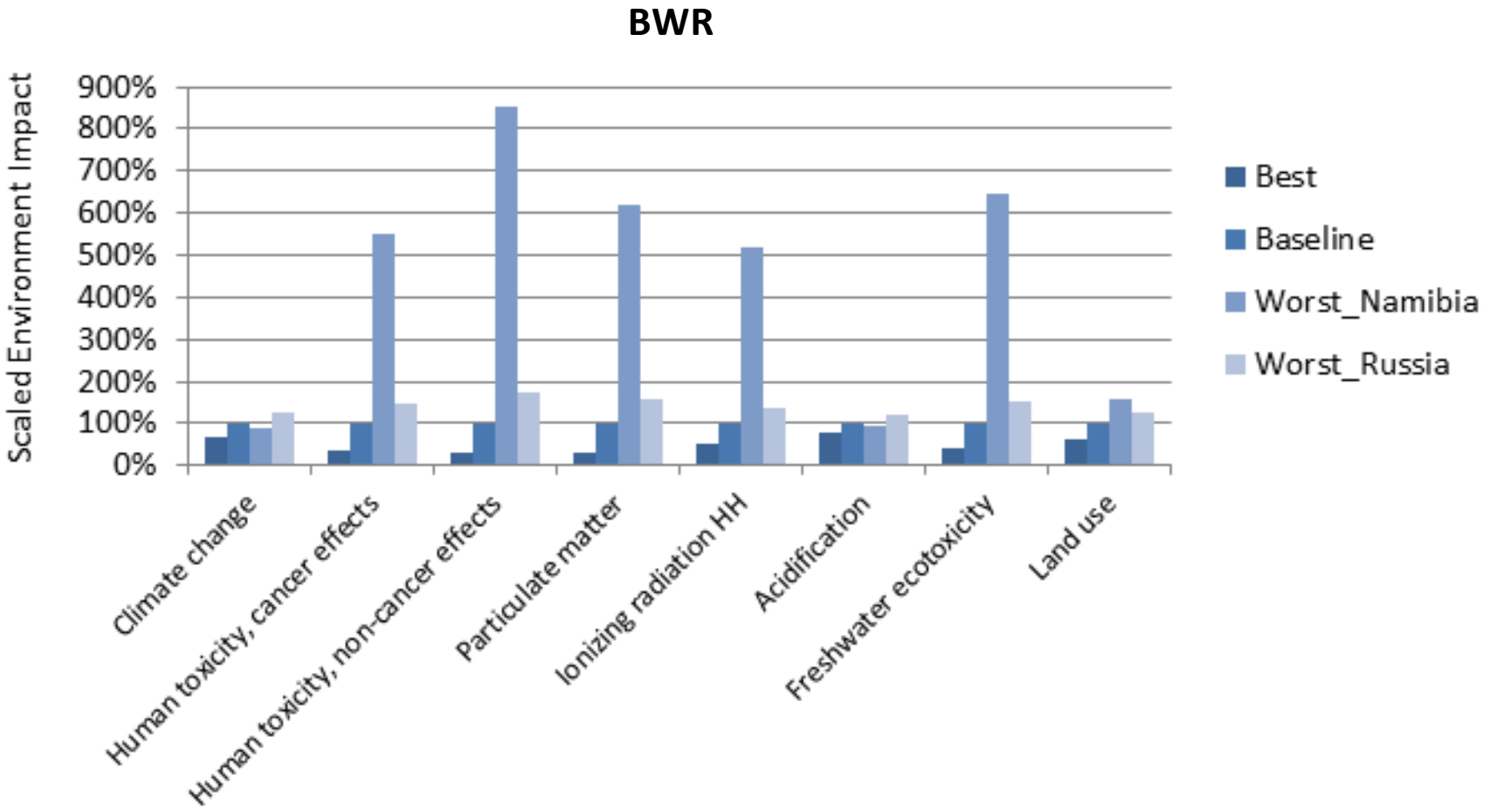
Risk Assessment

- Future Resilient Systems (SEC, NRF)
- Hydropower Accidents (NRP70)
- Geotherm-2 (CCES, CCEM)
- SAMOFAR (EC)
- Critical Infrastructure Protection (FOCP)
- OPTIWARES (CCES)

Life Cycle Assessment of Nuclear Power in CH – Environmental Impacts of Electricity Generation Technologies

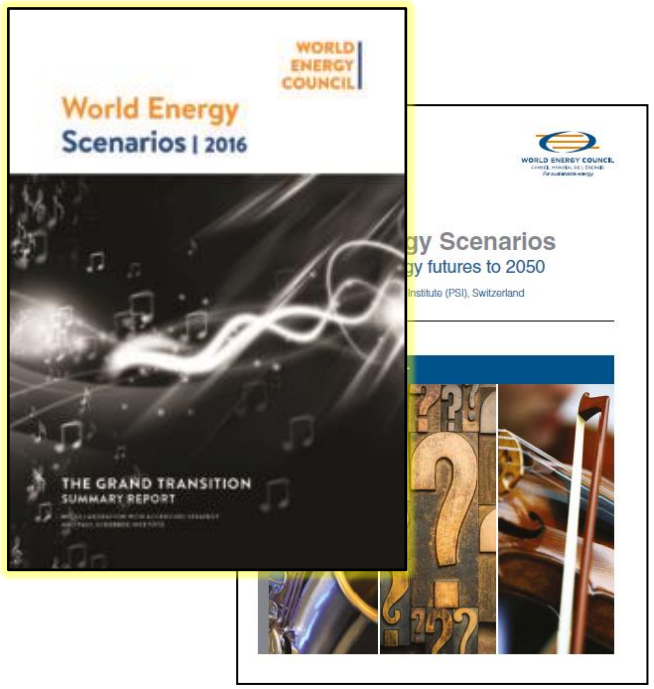


Life Cycle Assessment of Nuclear Power in Switzerland - Sensitivity of modeling choices



World Energy Scenarios 2016

- WEC partnership with PSI and Accenture Strategy
- Highlight at the 23rd World Energy Congress
  → 9,000 participants including head of states and CEOs
  → PSI present with 3 representatives
- **3 scenarios of the energy system** with regional-socioeconomic factors; continuation of 2013 study

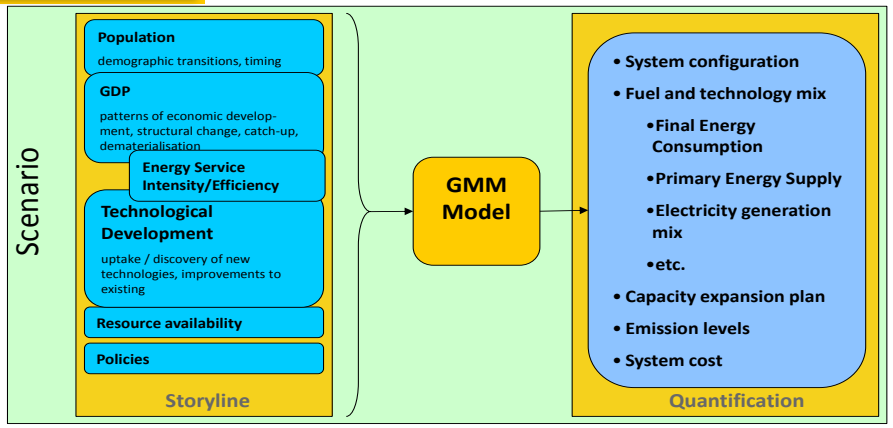


Modern Jazz (market oriented)
- Market chooses technologies
- Technology innovation
- Energy access for all

Hard Rock (fragmented policies)
- Low global cooperation
- Focus on energy security
- Best fit local solutions

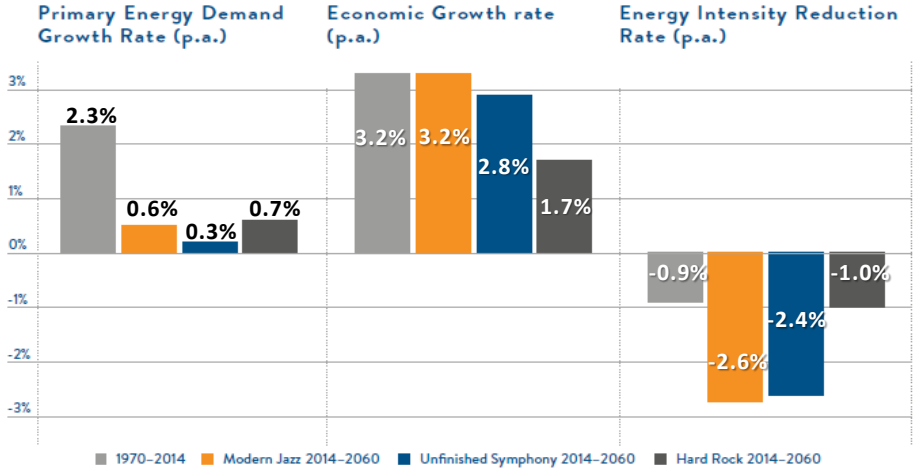
Unfinished Symphony (regulation oriented)
- Strong policies focusing on sustainability
- Unified climate action
- Targeted support for technologies

- **Analytical tool for quantification**:
  PSI's energy system model **GMM**
  – Cost optimal model with resources, energy flows, energy technologies and demand sectors in 15 regions

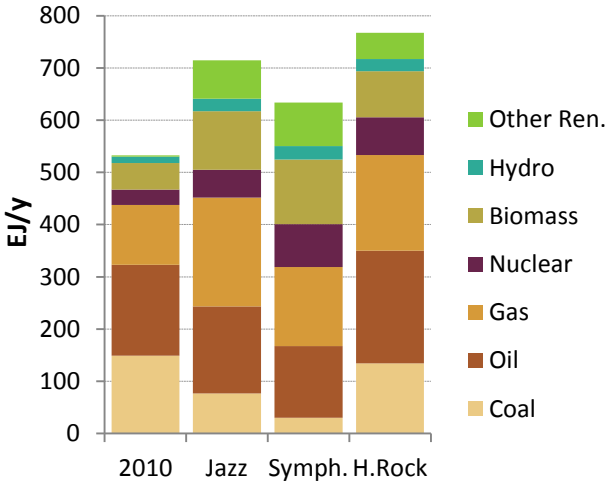


Energy demand and supply mix

- Slower energy demand growth due to:
  - Efficiency gains
  - Changes in demand patterns and behaviour

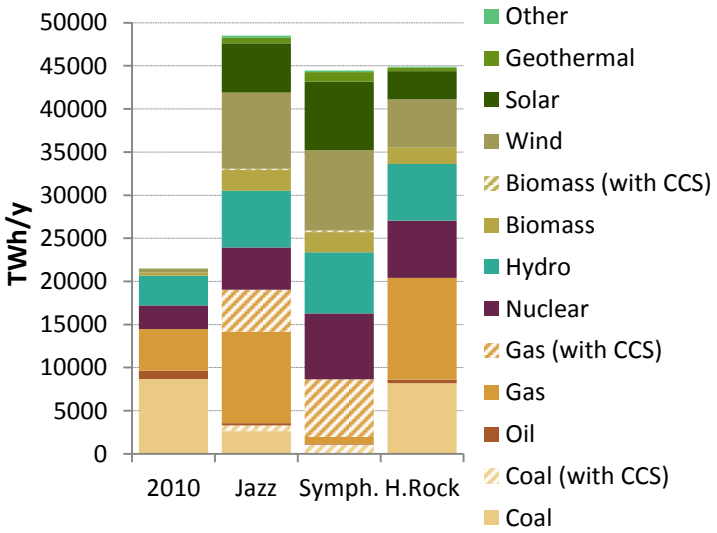


Global Primary Energy 2060



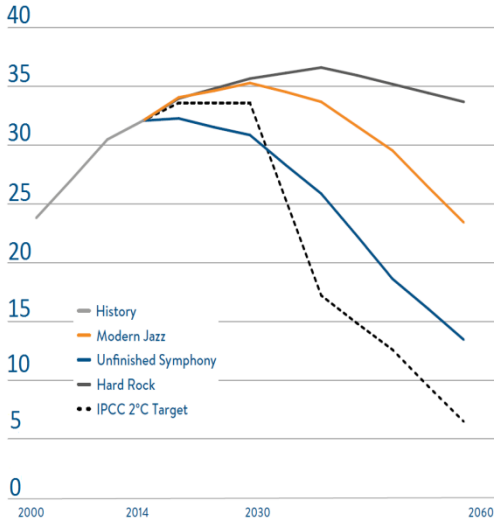
- Peak in per capita demand before 2030
- Fossil share falls: 80%(2010) →60%/50%/70%

Electricity Production 2060



- Less CO2 intensive electricity: 67%→30%/3%/45%
- Investments in infrastructure: 55/59/48 trillion USD2010

CO2 emissions



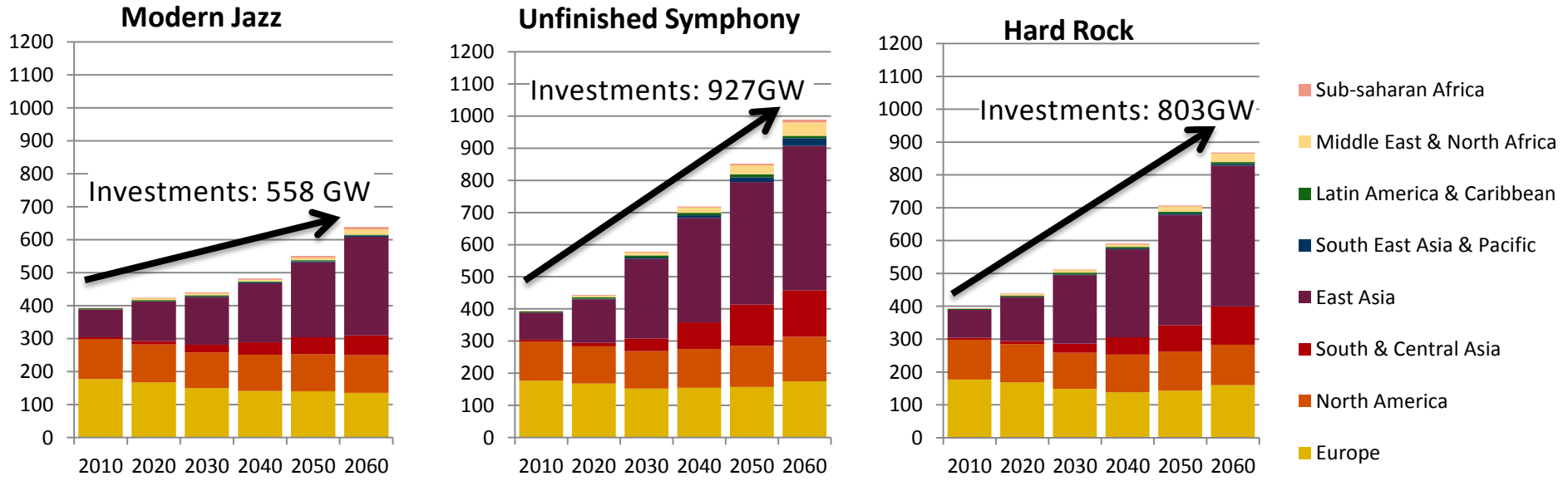
- Jazz is on track for +3°C
- Symphony is slightly above +2°C
- H. Rock is on track for 3.5 - 4°C

Nuclear: Installed Capacity in GW

Modern Jazz (market oriented)
- limited market for large-scale projects
- slowly emerging, regional CO_2 markets
- some nuclear plants under construction are not commissioned

Unf. Symphony (regulation oriented)
- nuclear growth is enabled by states because of security of supply (quasi-domestic)
- internationally convergent ,more stringent CO_2 price

Hard Rock (fragmented policies)
- nuclear growth is enabled by states because of security of supply
- low economic growth hampers investments



- China in 2060: +193 GW in Jazz, +333 GW in Symphony, +340 GW in Hard Rock from 2010
- India in 2060: +53 GW in Jazz, +132 GW in Symphony, +106 GW in Hard Rock from 2010
- Cumulative undiscounted investment in new nuclear capacity (in billion USD2010):
  - Jazz: 2300 , Symphony: 3500, Hard Rock: 3200

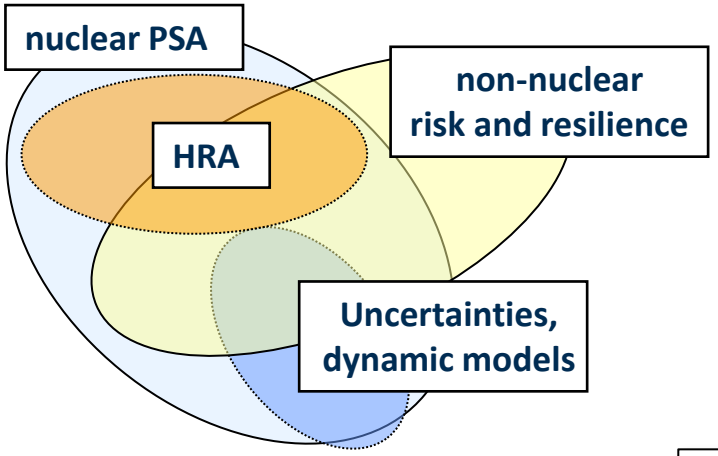
LEA Risk and Human Reliability – projects

ROES – Reliability of Operators in Emergency Situations (ENSI)

Decision errors, HRA data collection and its quantitative application

Nuclear regulatory support (ENSI)

Review of licensee HRA, sequence modeling, procedures



FRS - Human performance & sector resilience (NSF, Singapore-ETH Centre)

Foundations and methods for Human Reliability in diverse domains

Radiotherapy HRA (PSI Center for Proton Therapy, CROSS)

HRA for human-centered processes, emphasis on healthcare

Uncertainty propagation in dynamic PSA

Impact of model uncertainties on risk

EXAR extreme flood hazard (BAFU & federal offices)

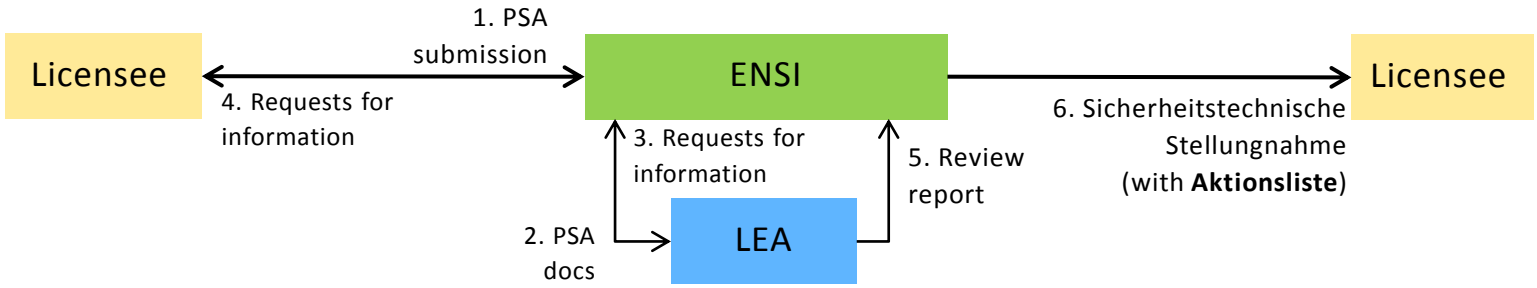
Synthesis and probabilistic hazard estimation (WSL/PSI)

LEA activity in support of Regulatory Safety Reviews

In Probabilistic Safety Assessments (PSAs), approx. 20-80% of the Core Damage Frequency includes a human failure event contribution

Good quality Human Reliability Analysis is key to ensuring a representative risk profile

How LEA is involved in the regulatory review process (Periodischen Sicherheitsüberprüfung, PSÜ)



Review Task

- **Basis**: PSA quality standards, Swiss, International, US
- **Goal**: ensure adequacy of the methods used, compliance with state-of-the-art/practice, adequacy of the analysts' assumptions
- **Focus**: on risk significance

LEA regulatory activity other than PSÜ

- Follow-up to Licensee implementation of Aktionsliste
- PSA-informed review of procedures (emergency, accident management, SAMGs)
  - Review of procedural support in PSA-important scenarios
- Evaluation of post-Fukushima safety upgrades
  - Implementation as well as integration in PSA
- PSA-informed analysis of plant automation in design-basis accidents (30-minute rule, Article 10 of the Swiss Kernergieverordnung)
  - Method to process the many (~10^5-10^6) PSA accident sequences to identify potential violations of the rule

In total, 6 to 10 person-months per year

LEA support of Regulatory Safety Reviews - types of issues found

Dependence analysis: in sequences with multiple human failure events, probabilities of subsequent events may require adjustment

IE	01TH011V06TC	OP_yyyyy	01NH011P06FR	OP_xxxx
IE	03TH012V09BO	01SY011P06FR	OP_jjjjjj	OP_FJZ
…				
IE	02RF11V07BO	01SY022P06FR	OP_xxxx	OP_xyz

Review issues: no documentation of the process to identify combinations; no dependence analysis for some sequences

Plant implementation (follow-up):

- systematic process implemented;
- about 100 combinations analyzed;
- Changes of 1-2 orders of magnitude for some probability values

HRA for plant hazard scenarios, internal & external
(e.g. internal fires and floods, seismic events)

Review issue: Influence factors not fully considered (e.g. effect of spurious signals and component activations, increased workload due to plant condition assessment)

Requirement to licensee:

- Adequately adjust human failure probabilities (baseline values for internal initiating events)
- Perform scenario-specific analyses

Note: seismic initiating events generally dominate total core damage frequency (>80%)

HRA for Accident Management and Severe Accident conditions

Review issue: Influence factors not fully considered: complexity (emergency measures have failed), procedures may not be as prescriptive as in emergency conditions; plant conditions are uncertain

Requirement to licensee:

- Include bounding assumptions in the performance conditions
- Enhance quality of qualitative performance analysis

Note: AM and SAMG actions are generally the top HRA contributors

The quality of Swiss PSAs is among the highest worldwide

Outlook

- SFOE Energy Perspectives: Potentials, costs and environmental performance of electricity generation options
- 2nd Phase SCCERs Supply of Electricity, Mobility, Storage & Joint Activities (CTI)
- Systemic contributions to Energy Systems Integration Platform (PSI/Swissgrid)
- Integration of intermittent renewables in the Swiss energy system and decentralized supply
- Risks and costs of advanced nuclear designs (VSE)
- Electricity market analysis (SFOE, VSE)
- Finalization of current EU projects and new proposals
- New global or regional scenarios (WEC)
- Continuation of HRA research project and on-calls (ENSI)
- Extreme flood hazards (FOEN)
- Consolidation of Singapore Future Resilient Systems project (NRF)
- Further tool and database developments
- Recruitment campaigns (particularly RHR; successor Head LEA)

PAUL SCHERRER INSTITUT

Wir schaffen Wissen – heute für morgen